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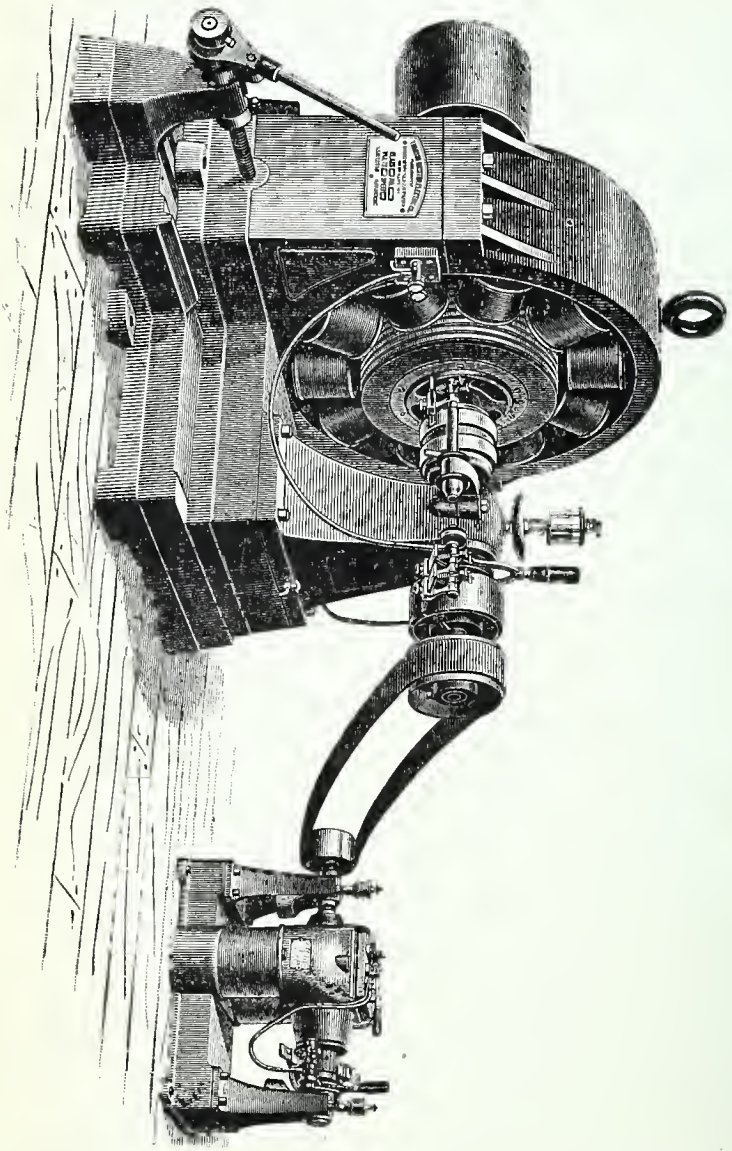

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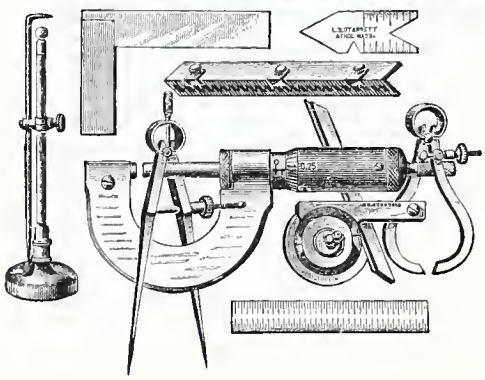

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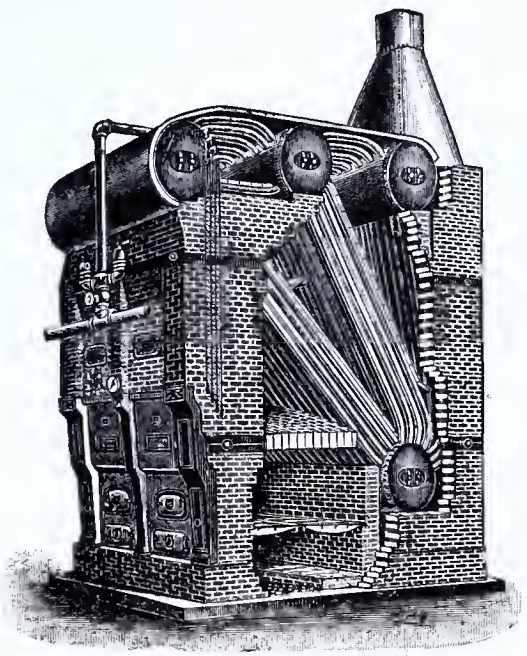

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PUBLISHED BY THE ENGINEERING SOCIETIES OF THE

UNIVERSITY OF ILLINOIS.

CHAMPAIGN, ILLINOIS,

1891-92.

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OFFICIAL NOTICE

THE TECHNOGRAPH is published annually by the Civil Engineers' Club, the Mechanical and Electrical Engineers' Society, and the Architects' Club of the UNIVERSITY OF ILLINOIS, and is the successor of "Selected Papers of the Civil Engineers' Club," of which four numbers were issued.

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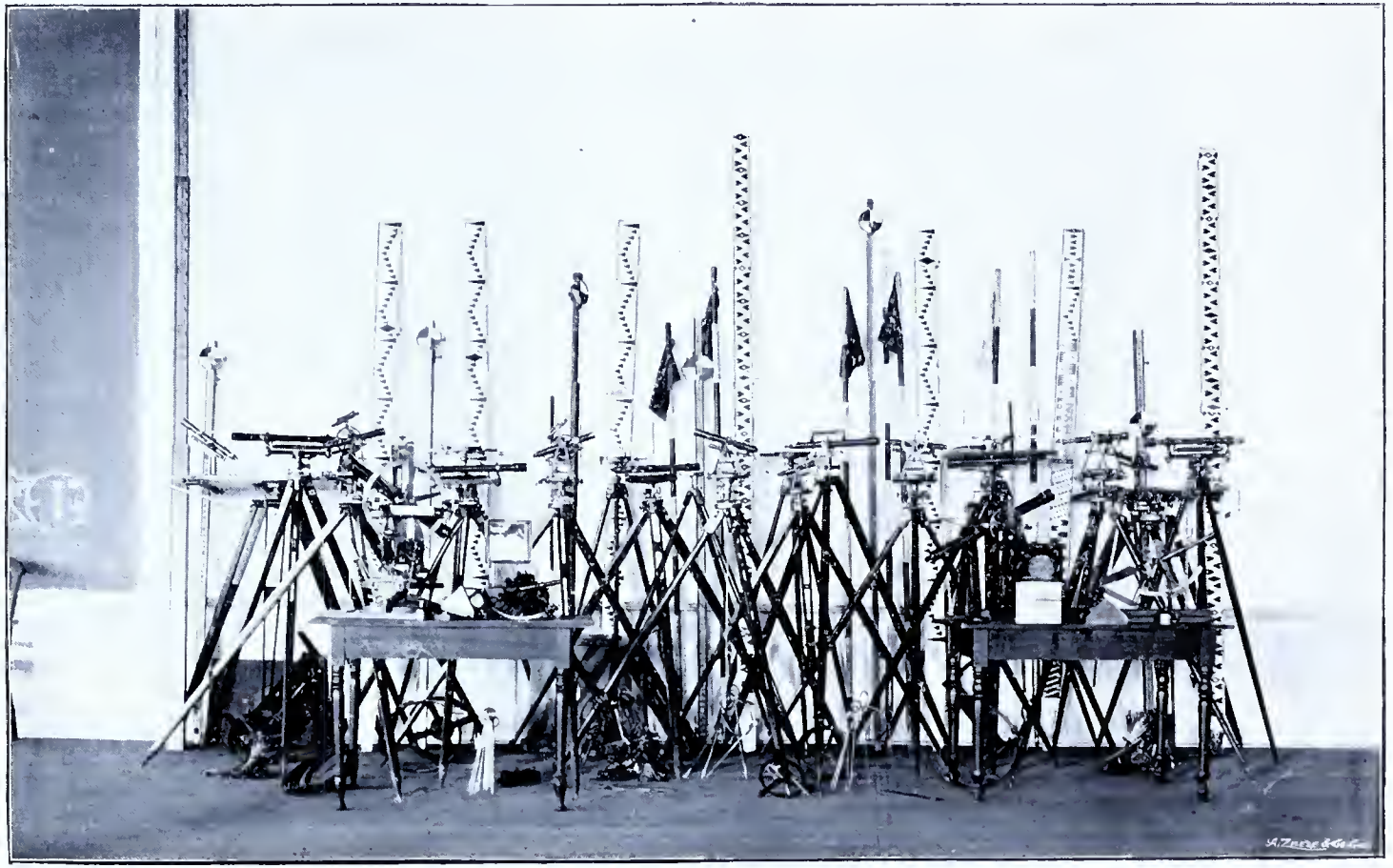
ENGINEERING INSTRUMENTS AT THE UNIVERSITY OF ILLINOIS.

The faculty firmly adhere to the belief that a large amount of practical application of the theories taught is indispensable to a thorough understanding of engineering subjects. The methods of instruction are based on this belief, and consequently necessitate the use of numerous engineering instruments of all kinds. This requirement has always been met in the most liberal manner by the college authorities.

Throughout the whole college year classes in civil engineering from the second, third, and fourth years are at work in the field on problems in land surveying, topographical surveying, railroad location, geodesy, etc., and the arrangement is such that no work is ever delayed by the lack of instruments. The classes in mining engineering are also well provided with instruments especially adapted to mine surveys

An unusual feature of the department of enginecring, and one that has given great satisfaction, is that the students have at all times access to, and unrestrained use of, all instruments required for the proper execution of their work. Some of the instruments have been in constant use for a quarter of a century, and have been taken to pieces and put together by every civil engineering class that has entered the university; and yet they are in fair condition. The students are proud of the instruments and consider it their duty to use them with care and to keep them in good condition. No important injury has ever been done to any instrument; and such damages as the breakage of rods or tapes, or the loss of arrows, etc., are paid for by the students, but this amounts usually to a merely nominal sum.

The astronomical observatory is provided with a 12 inch alt-azimuth instrument reading to seconds, an astronomical transit with attachment for zenith telescope work, two sextants reading to 10 seconds, three chronome ers, and a set of meteorological instruments.



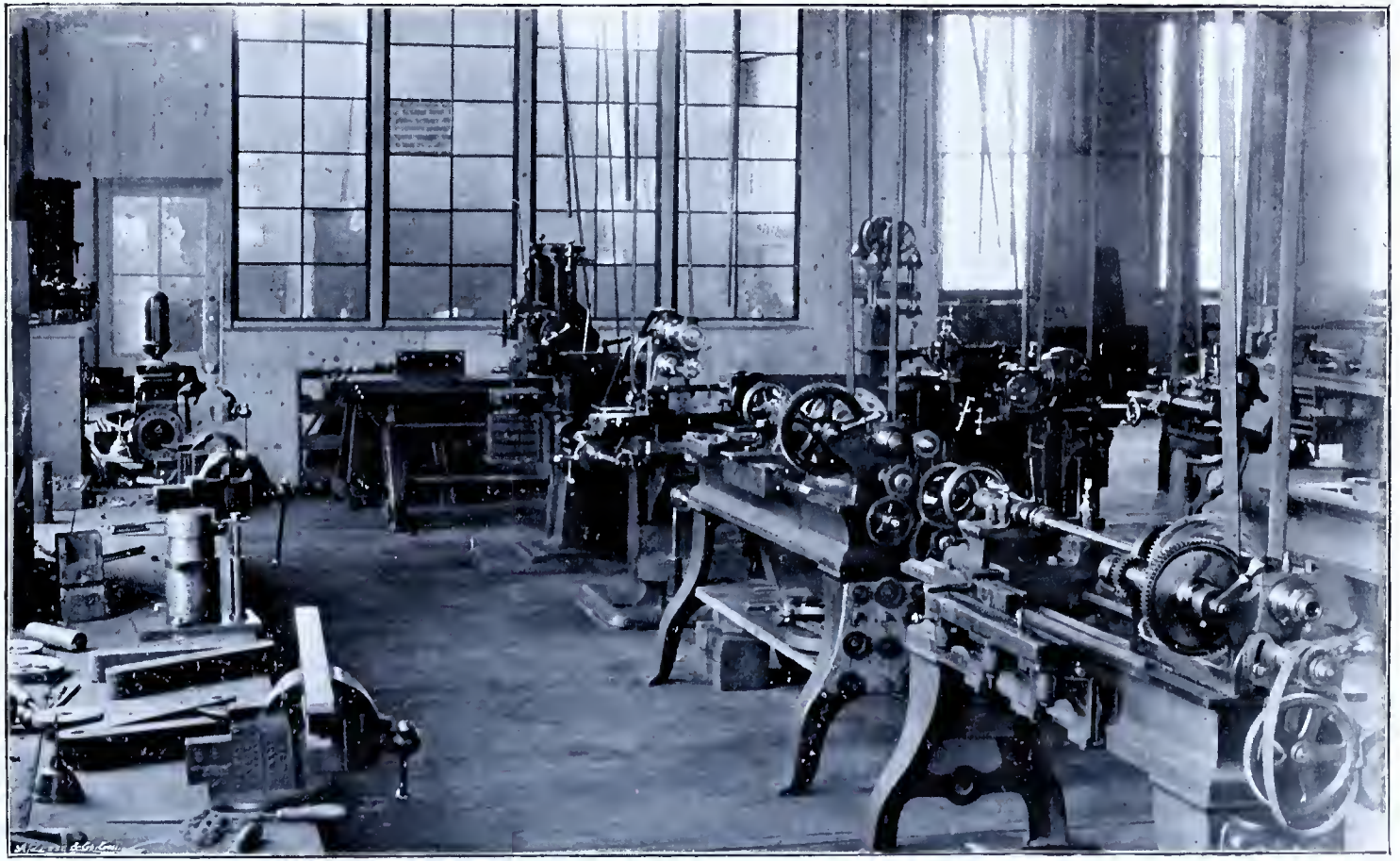
COLLECTION OF CIVIL ENGINEERING INSTRUMENTS.

THE MECHANICAL LABORATORY.

The mechanical laboratory is of brick, 126 feet in length and 88 feet in width. It contains a machine shop, blacksmith shop and foundry, shops for carpentry and cabinet-making, and a testing laboratory.

The machine shop occupies a room 124x80 feet and contains twelve engine lathes of different makes, varying from twelve to twenty-four inch swing, ten hand lathes, a planer, two shapers, three drill presses, a small milling machine, a universal milling machine, a universal grinding machine, sixteen vices with corresponding benches, standard calipers, gauges, taps, dies, drills, reamers, etc. Thirty two cases of pattern maker's tools with suitable benches. The blacksmith shop contains sixteen forges with power blast, and an equal number of anvils with equipment. The foundry contains a cupola for melting iron, a moulding floor with sand, flasks and the necessary small tools sufficient to accommodate sixteen persons. The carpenter shop contains an endless bed surfacer, pony planer, moulding machine, tenoning machine, shaping machine, jointing and rabbeting machine, boring machine, morticing machine, scroll saw, six sets of carving tools, and forty-eight cases of cabinet maker's tools with suitable benches. The testing laboratory contains a Riehle testing machine of 100,000 pounds capacity, a Riehle cement testing machine, hydraulic apparatus for determining the flow of water through orifices and over weirs, friction brakes and transmitting dynamometers suitable for carrying on a large variety of tests, a mercury column for the accurate testing of steam gauges, a stone grinder for preparing test pieces of stone, a machine for testing the resistance to abrasion of brick, standard scales, weights, measures, measuring instruments, etc.

The fifty horse-power engine furnishing power to the mechanical building was finished by the students of mechanical engineering. In the same room is a thirty horse-power engine fitted for indicator and brake work. A surface condenser and pumps, for experimental purposes, may be used with either of the engines. The boiler room, 32x36 feet contains two fifty horse-power boilers which may be used separately or together, and also contains necessary pumps, tanks, weighing apparatus, calorimeters, etc., for making complete tests of the economy and capacity of boilers.



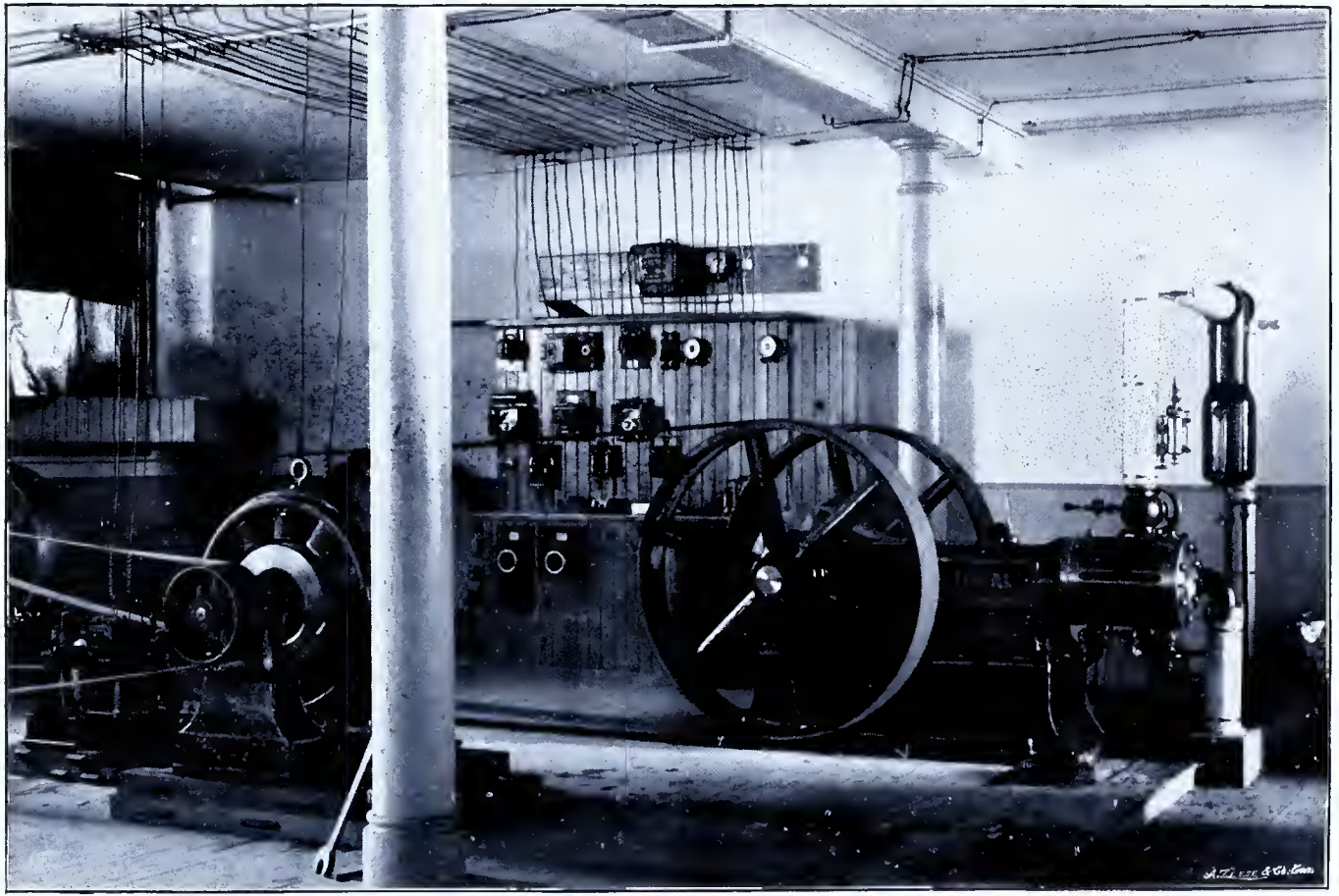
VIEW OF CORNER OF IRON-WORKING SHOP.

ELECTRICAL ENGINEERING.

This comparatively new department of the University has for its quarters the entire ground floor of the east wing of the main building, also a large lecture room for physics and electricity on the second floor. The lecture room is well equipped for illustrating all of the more important electrical phenomena. It is supplied with current from the dynamos and storage batteries in the basement, and is wired for both arc and incandescent lighting. The lower floor is occupied by a laboratory, dynamo room, battery room, photometry room, and a room equipped with tools for the repair and manufacture of special and experimental apparatus.

The dynamo room has for power a fifteen horse-power gas engine and a sixty horse power high-speed steam engine. The dynamos are connected to the main shaft and so arranged that either or both engines may be used. Several of the leading types of dynamos and motors are represented and more are soon to be added. The battery room is provided with a large storage battery made by the department and a collection of the leading forms of primary batteries. The room is to contain a tank and cable for localizing of faults, testing of insulation, etc.

The instruction in electricity begins with the third term of physics in the sophomore year, which is devoted to lectures and text book work upon the theory of electricity and general electrical phenomena. In connection with this is taken up in the laboratory the simple problems in electrical measurements, which are designed to acquaint the student with electrical terms and the use of electrical apparatus. Later on the student in the more advanced electrical measurements, takes up the testing of primary and secondary batteries for efficiency, cable testing, designing of electrical machines, installation of light and power plants, the transmission of power by electricity, and lastly photometry.



ELECTRICAL ENGINEERING.—PARTIAL VIEW IN DYNAMO ROOM.

THE ARCHITECTURAL ROOMS.

The architectural rooms are situated on the fourth floor of the main building in the east wing. They are well lighted, having a sky light over half their area. Recitations are conducted in these rooms, which contain from seventy-five to one hundred drawing desks. The imperative necessity of an engineering building is here illustrated, since the architectural rooms offer better facilities than any of the other engineering rooms.

The room shown in the cut is used as a class room by the seniors and juniors. Recitations are conducted in the eastern portion of this room near the windows. The cabinet contains a variety of catalogues, journals, etc., and a large collection of engravings and photographs mounted on bristol board and classified as described by Mr. White in an article in this number of THE TECHNOGRAPH. Above the blackboard is a large chart, some twenty feet in length, arranged by Professor Ricker for his classes in history of architecture. Each style of architecture is designated by a certain color, together with dates of their origin, flourishing periods, and decadence.

A smaller room, the entrance of which is directly in the rear of the professor's desk, is used as a private office by Professor Ricker and his assistant, Mr. White. This room contains a number of the latest improved computing machines, an architect's level, two large upright drawing boards, and a private library.

Mr. White's room connects with the designing room by folding doors and is used as a class room by the Sophomores in construction and drawing. Both rooms open separately into a long hall, which again opens into the main hall. The rooms are open all hours of the day including Saturday.

SENIOR ARCHITECTURAL DRAWING ROOM.

THE TECHNOGRAPH.

No. 6. UNIVERSITY OF ILLINOIS. 1891–92.

THE BUILDING PROBLEM IN CHICAGO FROM AN ENGINEERING STANDPOINT.

By Gen. Wm. Sooy Smith, Consulting Civil Engineer, Chicago.

A lecture delivered before the engineering students of the University of Illinois.

Young Gentlemen: I assure you that it gives me sincere pleasure to meet you this evening. It carries me back to the days of my youth when I was a struggling fellow trying to get a knowledge of the sciences that lie at the basis of the great engineering profession. I sympathize with you most heartily, most deeply, most sincerely, in every effort you make to prepare yourselves for the duties which will devolve upon you. The duties of the civil engineer are peculiarly responsible. The lives of your fellow-men are often involved. You can not be too scrupulous, too conscientious, too faithful, in all your studies, and hereafter in your practice as civil engineers. Above all there are no qualities so essential as strict honesty and truthfulness. I have seen many a brilliant engineer go under by yielding to temptation. The engineer who stands firmly by his convictions, does his work faithfully and honestly, and is well prepared, is bound to succeed in a great and developing country like ours. Be hopeful, aim high, work hard, be honest and faithful, and just as surely as you live success will come to you.

I congratulate you on being students of a great institution like this, so munificently endowed, so fully equipped, with such an able and faithful faculty, and with a curriculum covering every necessity. With the advantage of such a preparation you cannot fail to succeed, if you will improve the opportunities here so generously set before you. I need not go back into the history of this institution. I

need not inquire what your instruction has been. I have had samples of its products, and, as they buy grain on the Board of Trade at Chicago by sample, so I am always willing to take graduates of this University to the full of my requirements and pay the highest market price.

Our theme this evening is The Building Problem in Chicago from an Engineering Standpoint.

Let us first consider the existing conditions in the City of Chicago which control the character of its great buildings. There are no special difficulties which have to be overcome in the construction of ordinary light ones.

The main business of the city took up its residence at an early day on the narrow strip of land lying between the south branch of the Chicago River and Lake Michigan, and it has clung persistently to the northern end of this strip, only extending southward as its increasing volume demanded more space. This has been mainly due to the fact that the territory under consideration is most easy of access to the people living in the three divisions of the city. As a consequence of this concentration of business on this small area property lying within it has always been very valuable as compared with that exterior to it. This fact has made it a great object to owners to build very high buildings on their lots.

In the very "nick of time" the elevator put in its appearance to make a sixteen-story building WITH IT more convenient than a four story one had been WITHOUT IT. And so it is practicable, on a given area of ground surface, to get four times the rentable floor space that could have been had with the old-fashioned four-story buildings; and four times as many business men can now occupy such surface as could before the construction of the tall buildings; and this effects a four-fold concentration, and gives the lots a greatly increased value. The rental of offices in the business district amounting to about $1.50 per square foot per annum, landlords were naturally anxious to build many-storied buildings, and to economize floor space to the last degree. And "Presto Change!" each new building was planned higher than its predecessor, and even some old buildings put on new airs and new stories. Up went the eyebrows of our good citizens at these "Towers of Babel," and up went the citizens themselves into them—with some misgivings at first lest they should be dropped through one or two hundred feet by the breaking of a cable, or by failure of some part of the

hoisting apparatus. But these fears soon disappeared—as scarcely any accidents of this kind ever occur—and less harm to life or limb comes from this late great help to civilized life, than from the old-fashioned stairway, up and down which struggling humanity has been plodding its weary way through all the generations of the past. Convenience sanctions the tall building which necessity demands, and it has come to stay, and to draw the most diligent and energetic population on the face of the earth nearer and nearer together, and thus facilitate its labors and expedite its business transactions.

But a tall building, if of the same construction as a low one, will be proportionately heavier. And here comes in the first troublesome condition of our problem. The city stands on a low, flat plane. The highest point in its original plat was but five feet above high water level in the lake. The grade of the streets has been raised, however, until the curb lines are now about 14 feet above city datum, or mean low water surface. The material underlying the surface is clay, varying in consistency from firm to very soft at different points and different depths, these variations occurring often within the area covered by a single building. Its sustaining power, as determined by many tests that I have made with actual loads, is from 2,500 to 4,000 pounds per square foot. It is the common practice of Chicago architects to load the soil at the rate of 3,000 pounds per square foot. Under this load a small initial settlement takes place within a few hours, due to compacting of the soil at the surface upon which the load rests, and in part, perhaps, to displacement of water from the earth immediately adjacent to this surface by pressure of the loads applied. No further measurable settlement took place during the time (some weeks) covered by my longest experiments; but experience with heavy buildings shows that in the course of months and years they do continue to settle when the soil is not loaded to exceed the limit above stated. Experience also shows that while the initial settlements under a given load may be uniform throughout the area covered by a building, the progressive ones may eventually so differ as to cause serious cracks and demoralization in the structure.

The slow progressive settlements result from the squeezing out of the water from the earth—as was clearly seen while the wells were being sunk under the stage of the Auditorium for receiving the hydraulic cylinders used for operating the scenery. I sank these wells

after the adjacent walls of the building were built. Some of them went to a depth of 24 feet below the footings of the foundations and were only 4½ feet from them. The weights resting on the soil amounted to 30 pounds per square inch, or 4,320 pounds per square foot.

I had made the borings and tests of the soil and knew the nature of the materials at different depths well. The clay, which was of the usual character when the borings were made, had all become compact and hard, and contained very little water—none had to be pumped while the wells were being sunk.

Extraordinary precautions were taken to prevent the movement of the earth around the walls, as such movement might have caused serious settlements of the walls. Strong steel rings were used, and tongued and grooved sheathing was driven outside these rings, and kept well in advance of the excavation as this proceeded. We got the wells down without the slipping of a spoonful of earth outside of them, and this without the difficulty anticipated,—owing to the improvement that had taken place in the material, as described

The method of designing and building foundations in Chicago was very clearly explained in a recent address delivered to you by one of our best known architects, W. L. B. Jenney. These foundations are detached and independent of each other, and of such area in plan as to equalize throughout all parts of the building the load per square foot which the underlying material has to sustain, and to keep this load within safe limits. Thus far, this has been thought to be the best that could be done to secure buildings against unequal or excessive settlements.

For greater safety another of our very ablest and most distinguished architects, Henry Ives Cobb, designed the foundation of the Owings building, making it one strong platform of steel and concrete covering the whole ground plan of the building.

Unfortunately, while the loads may be made equal, the strength of the soil to sustain them varies in many instances considerably, and unequal and troublesome settlements take place. And now we are face to face with the second great difficulty with which we have to contend.

In view of the great height, and consequent great weight, of our principal buildings, it is important that materials should be used in their construction which unite in the highest degree lightness and strength with the other qualities of good building materials. And

so steel naturally came to the front with strongest sinews and head erect—too proud to bend—saying to the architect and engineer "Pile your mountain loads on my shoulders, and place them in the firm grip of my hands, and I will hold them for centuries, though the storm wrestles with me and the earth quakes beneath my feet." The men of science accepted the proffered service, and the men of affairs poured out their money to pay for it. And as a great building now goes up in Chicago, a gaunt skeleton of steel first rises aloft, which is gradually clothed from story to story with a rigid flesh of stone and brick, tile and mortar; and with such integument it becomes a habitable edifice.

But with each change of temperature the steel skeleton expands or contracts and becomes a creeping, crawling thing, apparently striving to throw off its clothing—especially if exposed to such heat as results from the burning of the great quantities of combustible materials collected and stored in a mercantile building, or from the occurrence of great heat in the burning of adjacent buildings; and this last danger may threaten even an office building, which itself contains very little combustible material. And this in spite of the means usually employed to protect the metal from heat,—the tile covering put upon it. For this covering will become so hot as to conduct enough heat to the steel to expand it and to crack off the tile. This has happened already—notably at the burning of the Tribune Building at Minneapolis about two years ago, which resulted in its utter destruction.

There may be steel buildings in which the fireproofing has been so well done that they will pass through an ordinary fire without such failure; but if the steel becomes even moderately heated, its stiffness will be measureably diminished, and the strength of the upright members so reduced as to cause them to bend and yield. This is the more likely to occur since the horizontal beams and girders will at the same time expand (unequally from the different degrees of temperature) and throw the posts out of vertical and into buckling positions, in which case the building will be likely to come down with a crash. It is as if a man was required to stand upright and take upon his shoulders all he could stand under, then take a strong dose of physic and have some one push his knees from under him. Here is the third difficulty.

Under these circumstances, if floors were built of perfectly rigid materials the unequal settlement would crack them into pieces and

ruin them. The elasticity of the steel beams now used in the floor systems partially obviates this difficulty, but not wholly, as many floors in which they are employed—notably those of the post office and custom house buildings—are badly demoralized and broken up by unequal settlements. This is the fourth difficulty, and our present system does not seem to provide for it satisfactorily.

But supposing we have succeeded in overcoming the great difficulties already pointed out, if steel and iron are used as principal parts of our buildings, and if these parts are not perfectly protected from corrosion, the building will still be comparatively short-lived.

There are many imperfections in minor details—such as weakness of brackets and their fastenings, want of proper provision for resistance of strains resulting from wind pressure, etc.,—which we need not here describe or discuss. They are only alluded to because they are liable to occur in the class of building we have under consideration unless they are guarded against by the architect who designs, and the superintendent or contractor who builds, the structure. There is little danger of such defects in the buildings planned by many of our excellent Chicago architects and erected by our many first-class builders. The well do not need prescriptions ; they are only for the sick.

Having thus considered the difficulties of our problem, let us endeavor to discover proper remedies for them ; for we perform the most valuable service when we do not merely discover a difficulty, but when we point out the best way to overcome it.

And first, we must, if practicable, secure an unyielding, instead of a yielding, foundation. In the central and northern parts of the city, near the lake, the soft materials described are underlaid by rock at a depth of from 60 to 100 feet. The rock rises to the southward and westward, coming to the surface at points in the western and southwestern parts of the city. Wherever it is practicable, the foundations of heavy buildings should rest upon the rock, or upon the hard-pan immediately overlying it.

As timber is everlasting under water, excavations for foundations can be made well below water surface in the lake, and piles can be driven in the bottom of such excavations down to the rock, or into the hard-pan immediately overlying it. These piles should be cut off at a level below that of any conceivable deep drainage system that may become desirable or necessary in the city (say, 15 feet below city datum). Platforms of timber and concrete should be

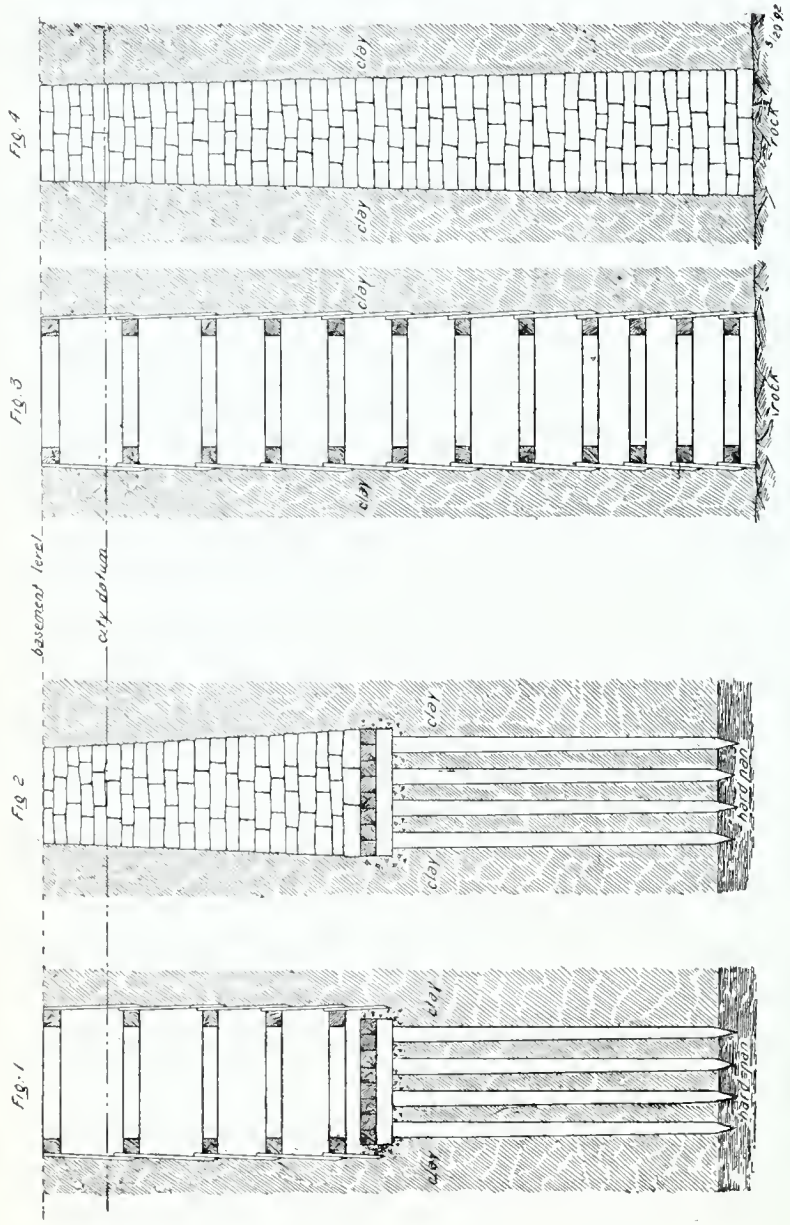
laid on the piles, and on these platforms, pillars or walls of masonry or concrete should be carried up to the level of the basements, or sub-basements of buildings. In this way sub-basements could be provided in which the machinery necessary for operating elevators and electric lights, and for heating and all other purposes, could be accommodated, leaving the first basements free for other uses, and thus making them rentable at high rates. The enhancement of the value of property consequent upon this increase of rents would far more than pay for the deep system of drainage, which the City of Chicago so much needs.

Where rock is found within easy reach, the excavations can be made to the rock, and the masonry or concrete construction can be carried up from the rock without the use of piles. (See Figs. 3 and 4, page 16). And so we may put unyielding and imperishable foundations under our buildings, and avoid all the danger and losses which may result from placing very high and heavy structures on comparatively soft and compressible materials.

A pile driven at the bottom of a pit 30 feet deep and well into hard-pan, or to the rock, where this is within reach, may be safely relied upon to sustain from 30 to 40 gross tons. When the weights of all parts of a building have been carefully computed, it is a simple matter to determine the number of piles required to sustain these loads. And in cases in which the rock is within easy reach by wells, say, at a depth not exceeding 60 feet, they may be sunk to the rock and a pillar or column of rubble masonry or concrete may be carried up to the level of the basement or sub-basement floor (See Figs. 1 and 2, page 16).

Careful estimates show that these foundations will cost less. than those which are now generally employed ; namely, platforms of steel and concrete, resting upon compressible soil.

Our safe and accomplished architects Adler and Sullivan have taken a long step in the direction of the plan of foundations above recommended, in causing piles to be driven under the foundations of the German Theater they are now building on Randolph between Dearborn and Clark streets. The foundation of the County Building in Chicago also rests on piles ; but these were so small and so carelessly driven that they are of nowhere near full value. Some elevators and warehouses, the Shot Tower, and other structures rest upon pile foundations simply, but I know of no instance in which wells or pits have been sunk and piles driven in the bottom of them in



FOUNDATIONS FOR COLUMNS IN BUILDINGS

1/4 in. = 1 ft

DESIGNED BY ..... Wm. Story Smith Civil Engineer

order to reach rock or its equivalent, and to place the pile heads and the platforms built on them below the level of perpetual moisture when the deep drainage the city so sorely needs has been secured; and there is no instance in which foundations of stone-masonry or concrete have been carried down to the bed-rock as here suggested. By the construction of foundations of this character, we dispose of our first, second, and fourth difficulties, namely: that of placing very heavy buildings on a weak soil, the unequal settlements of different parts of the same building resulting from the unequal sustaining power of the same soil, and the consequent cracking of walls and floors.

The third difficulty, resulting from the expansions and contractions of metals employed in the construction of tall buildings, may be obviated by protecting these metals absolutely from any considerable change in temperature, or by throwing out the metals altogether and substituting tile, brick, and stone as far as may be practicable. As the weights to be borne by the vertical members of buildings such as we have described, are very great, it becomes necessary to use materials and modes of construction which will make these vertical members as small in cross section as may be consistent with the loads they have to carry, in order to economize floor-space, which is the revenue-producing part of the building.

Now, first-class cut-stone masonry laid in hydraulic cement mortar has less than one fourth the compressive resistance of the stone of which it is composed. If, therefore, the stones themselves can be placed in absolute contact, without the interposition of mortar, it is fair to presume that much greater compressive resistance of the material would be obtained. To test the truth of this supposition I had a square pillar of Lemont limestone made by the Western Stone Company, one square foot in cross section and about 9 feet high. It was composed of seven stones taken from their thickest stratum, and so cut as to lay on the natural bed in the pillar when this was set up. The bearing surfaces of the blocks were planed perfectly true. I sent this pillar to the government testing machine at Watertown, Mass., and asked that it be set up by simply washing the beds with a very thin grout of the best English Portland cement. This pillar was subjected to the entire crushing power of the machine—800,000 pounds,—and it was only when the full strength of the machine was employed that the pillar showed the slightest symptom of yielding. Then small flakes were chipped

off of the outside surfaces of two of the blocks, which is proof conclusive that the pillar was on the point of yielding. If pillars or columns having a cross section of four square feet instead of one were used, the total resistance of such pillar to crushing would be far more than four times 800,000 pounds, for it is a well-known fact that the crushing resistance of any substance increases in greater ratio than the area of cross section of the test specimen.

If, however, we assume that the strength is increased in that simple ratio, a pillar of Lemont limestone two feet square made as already described, would sustain a weight of 3,200,000 pounds. One third of that load, or say 1,000,000 pounds, would be a safe load for such a pillar. If we add a covering 2 inches thick on all sides of a pillar—which is sufficient to afford it all necessary protection from fire if a method is used which will shortly be described,*—the whole size of the pillar so protected would be but 2 ft. 4 in. each way, which is but little larger than many of the steel columns with the fire-proofing now used. These pillars would, of course, decrease in size as the loads decrease, story by story, from bottom to top of the building. The blocks of which they are composed may be doweled by a steel rod running down through the center of the pillar and connecting cap plates of cast iron that should be put on the pillars at the level of each story. These plates may project sufficiently to furnish a support to arches of tile, or Beton Coignet, which should be used for the floor systems. In wide buildings the pillars should be set in lines at right angles to each other, and at suitable distances to make it practicable to construct the whole floor by a groined arch or dome system supported by these pillars.

This system of floor construction is by no means new, as it has been in use for centuries in Spain and Italy. It has been recently introduced into this country by a Spanish engineer, Mr. Guastavino, and has rapidly come into use in our eastern cities. It has been found practicable to make strong floors with a very slight rise of the arch in proportion to its span. Steel rods have recently been built into the material of the floors thus constructed, so placed as to resist the horizontal thrust of the arches.

*After the lecture the speaker exhibited a plate of a lately invented fire-proofing, consisting of a mortar composed of one fourth ground talc and three fourths plaster of Paris, spread upon the two sides of a steel-wire netting. The plate exhibited was about three quarters of an inch thick and 15 inches square. It was stated that this particular plate had been heated to a white heat on one side for half an hour, and then the other side placed on a man's hand who carried the plate away without any unpleasant sensation.—Ed. Technograph.

If the mode of construction here pointed out is adopted, the building would be practically unchangeable in its dimensions, indestructible by fire, abundantly strong, and as durable as the materials of which it is composed. It also seems, from the best estimates I can make, that a building constructed in this way will cost less than one with steel and iron framing.

Tile, brick, and stone do not corrode, and while mistakes may be made, and imperfections in design and workmanship are quite as likely to occur in the use of these materials as in that of iron and steel, these can be obviated in both cases by skill and fidelity, without which no system of building can be made successful.

As the subject of my talk to you this evening was ably treated from an architect's standpoint, for your benefit, recently, I am glad I have been honored with the privilege of discussing it from the point of view of an engineer. The two professions are closely allied, and each should lend a helping hand to the other whenever opportunity affords. In this spirit I have presented you my thoughts this evening, and hope they may be of some little benefit to you when you step out into the great working world, and put into use all that you can learn in this noble institution—the University of Illinois.

[Extracts from the above lecture were published in the Chicago dailies, and created considerable discussion among the architects of that city. Three of the most prominent architects have permitted us to present their views concerning the new form of construction proposed by General Smith.—Ed. Technograph.]

W. L. B. Jenney, a warm friend and admirer of Gen. Sooy Smith, says :

"I have seen Gen. Sooy Smith but for an instant, since he returned, but it seems to me the published account of his paper conveys rather a more sweeping criticism of the present building methods than he really meant. We all know there are some high buildings which are not sufficiently fire proofed, or, in general terms, are too cheaply constructed ; but we know also that the high buildings put up by reputable builders, architects, and engineers are entirely free from criticism on that score. All good builders will fire proof sufficiently to guard against any heat possible from the materials to be stored in the building, or from the burning of surrounding structures.

"There is almost no limit to the possibility of protection from

heat by fire-clay. Take for instance the huge blast furnaces used by the great steel companies. They are constructed of iron and steel, protected from heat by fire-clay, and in spite of the temperature being 3,500 to 4,000 degrees, and of the iron product raging in them at a boiling heat day and night, these furnaces last four years before they have to be renewed. We fire proof according to the use to which the building is to be put. For instance, in the Fair and the Leiter Building much greater precaution is taken than if they were to be used as offices instead of for storing highly combustible merchandise. It is entirely possible to make a fire-proof building which would stand the test of a fire from petroleum on every floor. The precaution that we take is enough and there is no use in taking more, because it would be a useless expense. These buildings are for an investment, and they must be made sufficiently substantial to serve the purpose intended, in the best possible manner—with due regard both to safety and to economy, not a dollar must be wasted,and on the other hand with nothing omitted necessary to insure safety.

"Gen. Sooy Smith mentions the Minneapolis Tribune Building as an example of a fire-proof, steel-frame building which went to pieces in a fire. That is not a fair example, as I have been informed, by one of the tenants of that building at the time of the fire, that the part that burned was never claimed to be fire-proof, and that the part of the building that was fire-proof did not burn.

"As for the use of limestone pillars instead of steel, limestone behaves worse than steel when subjected to heat, and to make it serviceable it would have to be fire proofed as much as steel, and worse still, they would from necessity be large and occupy valuable space. Limestone is friable and at a comparatively low temperature turns to lime.

"As to the deep piling with tops fifteen feet below datum, recommended by the General, while it would doubtless be a good thing, it is unnecessary in my estimation, and would be only a waste of money. The great high buildings put up on foundations supported by piers at datum are proving highly satisfactory. For instance, the Home Insurance Building has settled so uniformly that the greatest variation throughout is only three fourths of an inch. The difficulty with Gen. Smith's proposed sub-basement would be that large pumps would have to be constantly worked to keep it dry. Chicago sewers are about 2 to 4 feet above datum; and the large quantities of

seepage into a basement 15 feet below datum would entail a constant and heavy expense for pumping. In my opinion the objections to Gen. Sooy Smith's plan is that it is needlessly expensive. The present method of putting up buildings, if carefully and scientifically followed out, leaves nothing to be desired. Gen. Sooy Smith's ideas are above scientific criticism, but I am afraid it would be hard to persuade capitalists to pay the extra money to put them in practice. Nothing but an Eiffel tower would demand them."

Dankmar Adler, of Adler and Sullivan, says :

"I am disposed to think highly of any proposition made by Gen. Sooy Smith, as he is an undoubted authority on engineering subjects. His paper to the boys down at Champaign is a valuable contribution to architectural and engineering science. His plan is so wide a departure from current practice that I should not like to discuss it until I have given it more thought and study. General Smith is right in saying that piling should be sunk so deep that the tops of the piles will be perpetually below the water line. In the German Opera House, which we are building, the tops of the piles are 6 inches above datum. Unless the lake itself is lowered this will be deep enough for all time. The bottoms of these piles penetrate a very hard hard-pan which overlies the stratum of rock."

D. H. Perkins, manager for D. H. Burnham, says :

"I do not like to criticise so great an authority as Gen. Sooy Smith at a moment's notice. I will say, however, that we favor the iron and steel construction and look upon it as the very best there is. All our buildings for 1892 will be built in that way. In my opinion an iron or steel column covered with fire-clay will stand more heat than anything yet known. It will take more heat to penetrate this coating of fire-clay than will be generated by the combustion of any ordinary merchandise or furniture. As to the piling principle we do not use it and all our buildings stand on separate column footings which rest on the blue clay. We have not found that piles are necessary and our buildings have not suffered for lack of them."

FIELD RIVETING.

By Z. Foster, '92, School of Civil Engineering.

In designing field riveting it is the usual custom not to consider the friction between the parts joined, but to proportion the rivets so they will transmit the strain and have enough bearing area not to crush the metal. The pressure per square inch allowed for shop-riveted joints is generally reduced by one third for field riveting to allow for imperfections of field-work. The riveted field connections of floor-beams, stringers, struts, etc., must be accurately matched before leaving the shops, and all unmatched holes reamed to fit. All rivet holes of joint connections should be so accurately spaced that rivets of the proper size can be passed through all the holes in the joint connection after the parts are placed in position, without the use of drift pins. Wherever possible rivets should be driven with a machine, which "should be direct acting, capable of exerting a yielding pressure and holding on to the rivet after the upsetting is completed."

Machine riveters have steam, hydraulic, or electric power. The electric riveters have the advantage that they can be used at any distance from the original source of power, and do rapid work. The latest hydraulic machine is a French invention. It is claimed that it is capable of upsetting the largest rivet in from 8 to 10 seconds, and that with it one man can upset 1,000 to 1,200 rivets per day.

Most of the riveting required in the field on bridges or on buildings is done by hand-work. The ordinary rivet gang consists of two strikers, a holder on, and one man to heat rivets. Their outfit comprises a forge, tongs, hammer, snaps, dolley, drift pins, and rivet buster. When supplying one gang the heater usually has 4 or 5 rivets in the fire at one time.

The amount of riveting a gang can do depends on the character of the work, the accessibility of the rivets, the number of rivets to be driven in each connection, and upon the men who drive them. There is practically no difference between steel and iron riveting when men become accustomed to using the steel. In pin-connected bridges a gang of four men can drive on the average 125 rivets per day of 10 hours, and when the rivets are small or easy to get at 300 can be driven in one day. "On a lattice truss bridge 500 rivets can be driven in a day of 10 hours, the work being easily reached. On lat-

tice spans of from 135 to 150 feet a gang ought to average 400 rivets per day without trouble."

As the cost of field riveting is not often kept separate from the cost of erection of bridges, accurate data is hard to get. Bridge erection is contracted for by the lineal foot of span or by the pound of metal in the structure, and each item of cost is not given separately. In making estimates some contractors allow $1 per ton of metal for the expense of rivets and field riveting. A gang of four men costs from $13 to $15 per day of 10 hours, varying with the location of the work. The actual cost of field riveting will vary with (1) the designer, (2) the class of structures, i. e., pin-connected, lattice, plate girder, through or deck bridges, etc., (3) the location of the structure, (4) the time of year the structure is erected, and (5) on the amount of riveting a gang can do in an average day's work.

Mr. Lincoln Bush, class of '88, U. of I., gives the following as the result of his observation while inspector of erection on pin-connected spans of from 147 to 208 feet. "The cost is for actual time worked at driving rivets by experienced men, and does not include cost of false works and preparation for driving. For $\frac{7}{8}$-inch rivets the average cost was $4\frac{3}{4}$ cents per rivet, while 1-inch rivets cost from 10 to 15 per cent. more owing to the extra time and care in heating the larger rivets. The rivets in the drum of a draw span cost about 10 cents each. These prices include rivets that are lost from not being caught. Where loose rivets were found, they were cut out and replaced."

The estimated cost of field riveting, as given by engineers of bridge work, is: Berlin Iron Bridge Co., *"about 10 cents per rivet in place;" Phœnix Bridge Co., **"varies from 5 to 10 cents per rivet;" Missouri Valley Bridge Works,†"uses in making estimates 10 cents per rivet, though they sometimes cost more;" King Iron Bridge Co., ‡"varies from 5 to 20 cents." On lattice truss bridges, a gang of riveters costs $15 per day for 10 hours, and can drive on an average 400 rivets, which makes the cost $3\frac{3}{4}$ cents each.¶

"According to with Mr. S. V. Ryland, the contractor for

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*C. M. Jarvis, chief engineer Berlin (Conn.) Iron Bridge Works.
**J. Sterling Deans, Prin. Assist. engineer.
†A. J. Tullock, proprietor Missouri Valley Bridge Works.
‡F. C. Osborn, engineer of King Bridge Works.
¶A. Ziesing, U. of I. class of '78, superintendent of Lassig Bridge and Iron Works, Chicago.

the erection of the Hawkesbury bridge, the cost of the field riveting in that bridge was not far from 10 cents each, and many of the rivets cost over 20 cents each, the riveting being done by English and native workmen. The cost of field riveting in Great Britian as given by Sir Benj. Baker in a letter several years since, was: 'The floor of the Tay bridge, over 2 miles long and 26 feet wide, was all riveted up with portable hydraulic riveters in the field and cost 60 cents per 100 rivets. In plain girder work, field rivets driven by power usually cost on an average about 72 cents per hundred rivets. Joint covers, lattice, and connections cost from $1.92 to $3.36 per 100 rivets, or 2 cents to $3\frac{1}{3}$ cents each.' In one of our large railways where lattice and plate girders predominate, the field riveting costs about 5 cents per rivet, which includes many re-driven in old structures. The metal work of the Clyde Viaduct, on the C. M. & N. R'y. near Chicago, is made up of two pin-connected spans 148 feet and 162 feet and three plate girder spans 60 feet—all through bridges. The pin-connected spans had stiff bottom chords, and all had solid box floors. On this work the field riveting cost the contractor on the average a little over 5 cents each, not counting profit nor wear on tools, etc. A fair estimate of the cost of field riveting is 6 cents per rivet, though many field rivets in badly designed connections doubtless cost as much as $3 each, and some possibly $5, but these are occasional cases."*

In iron and steel building construction the number of rivets driven per day is about the same as in bridge work, and depends upon accessibility, fit of joint, etc. Purdy & Phillips, prominent civil engineers, Chicago, give the cost at from 4 to $4\frac{1}{2}$ cents per rivet in building construction, and "in making estimates the price should not be less."

The contract price paid in 1891, on the Wainwright, a ten-story building, St. Louis, was 8 cents per rivet. On the German Opera House, Chicago, the cost price is $5\frac{1}{2}$ cents per rivet. In the Cook Co. Abstract Building, Chicago, 17 stories, the cost is $5\frac{3}{4}$ cents per rivet. On the American Express Co's. barn the field rivets were driven for 4 cents each. In this barn the rivets were easy to get at, yet the men scarcely made ordinary wages. The weight of iron and steel in this barn is estimated at 1,450 tons, in which will be used 12,000 three-fourth inch rivets, costing about $2\frac{1}{2}$ cents per pound; and with riveting at 4 cents, the cost of field riveting per ton of metal is about $0.44. This is probably lower than the average cost.*

*A. F. Robinson, U. of I., class of '80, formerly bridge engineer of C.M.& N.R'y.

*The above data on field riveting in iron buildings was received from J. H. Frederickson, class of '91, U. of I.

FOUNDATIONS FOR BRIDGES.

By P. Mogensen, '94, School of Civil Engineering.

Probably one of the most varied subjects submitted to the consideration of civil engineers, is the design and construction of bridge piers. From the simple wooden trestle and the equally simple crib built of ties and used for temporary purposes, to the gigantic pier of the Firth of Forth bridge innumerable gradations are found, and in many cases the engineer is called upon to overcome seemingly insurmountable difficulties in connection with such works. It is far beyond my power to treat of any part of the more intricate structures ; my object is merely to call attention to a few simple details in the construction of masonry foundations in shallow rivers where underground water is encountered, or in other words, where pumping is required.

The surface-water is often a source of great trouble, and claims the attention of the constructing engineer as soon as the location of a bridge has been fixed, especially if a stream is found running where excavations are to be commenced. To make the position of one or more piers accessible, it will generally be found convenient to divert any such stream. It is not essential that the diversion be made close to the bridge; it may be effected where it can be done at least expense. However, as such diversions generally require dams, it should be within a reasonable distance for easy inspection.

When the river-bed consists of sand, a secure foundation may be made by sinking cylindrical wells to a depth of say twenty feet, but in all cases lower than any underground current that might be met with. The depth to which the wells must be sunk, naturally depends upon the resistance offered by the sand, the number of wells employed, the weight they are required to support, and other considerations.

Where a large pump is required, the inside diameter of a well should not be less than six feet, or large enough to enable two men to work along-side the suction tube. The wells should be built of bricks in cement mortar, to a height of about ten feet above ground before the sinking of them is commenced. A strong wooden frame should be placed under each well and another on the top of the section built, both being firmly fastened by strong bolts passing through the brick work. The top frame may be removed when it is required to add to the well.

Whatever the number of wells in a pier, they should be sunk simultaneously. This is done by loading the top frames with long, heavy objects such as rails, girders, etc., for the purpose of forcing the wells down when the material underneath the bottom frames has been removed. If the amount of water flowing into two or three wells does not exceed the capacity of one pump, the water should be drawn from a well sunk somewhat deeper than those adjoining, which are by this means drained. The excavated material is taken out with a small windlass.

The pump should be fastened to a wooden frame, placed on the top of the objects used as weights. A derrick with blocks and tackle should be erected over the pump and kept in readiness for raising the suction tube whenever the foot-valve fails to act. If a sliding suction is used, it should hang supported in the pulleys. Sometimes the pump may be entirely dispensed with. The wells are then excavated by means of grab-winches, the buckets of which fill automatically when let drop on loose material. It is needless to say that this method will be impractical when stones of considerable size, trunks of trees, or other obstructing bodies are encountered.

When the wells have been sunk to the required depth, they should be filled with cement concrete up to ground level, where neat work may conveniently be commenced. Small arches should be built to support the body of the pier where it overhangs the openings caused by the curvatures of the wells.

Instead of brick wells iron cylinders are advantageously employed where they can be procured at a relatively low price, and especially where a large diameter is required, as in this case the brick wells are liable to collapse. The iron cylinder has the further advantage of presenting a smaller annulus to be cleared at the bottom, and having a smoother outside surface its own weight is often sufficient to force it through the ground. The methods of sinking iron cylinders and masonry wells are essentially the same.

Where the river-bed consists of layers of sand and rough gravel mixed, with or without a certain amount of smaller and larger stones interspersed, it will be found cheapest and quickest to make an open excavation without lining or shoeing of any kind except in the pump-well. This can be done by giving the sides a slope of one half or three quarters to one. The excavated material can be taken

out either with a crane or with wheel-barrows, and should be placed in such a position as to offer additional security against any breakage in dams, floods caused by heavy rains, or other natural agencies.

The pump-well should be made in one corner of the excavation, and for a pump of from five to ten inches bore a well with an area of twenty or twenty-five feet is required. This can be sunk advantageously by placing planks about six feet long on end and outside of two wooden frames, one about a foot from the bottom end and the other close to the top.

As the excavation inside this lining proceeds, the suction tube should be lowered, and whenever the lower end of a plank has been left free by picking out the obstructing material, it should at once be driven down as far as possible. By giving the part of the well above the lining a slope of about one half to one only one length of planks will be required, and this method will be found cheaper and more convenient than lining the well through the whole depth. The well should be continually at least two feet lower than the excavation so that this may be the better drained.

Many engineers, when not directly interested in the cost of the work, disapprove of the idea of making an open excavation in water-bearing ground without lining, and generally suggest some more complicated method. It is true that the open excavation requires of the constructing engineer his personal supervision of details, which means hard work ; but it is also true that, when at all practicable, this is by far the cheapest way of doing the work.

Under circumstances as those described, it is customary to place the brick or stone masonry on a concrete foundation of from one to two feet in thickness and with an offset of nine or twelve inches on all sides. When, therefore, the excavation is down to the proper depth and the bottom has been made as nearly as possible the exact size of the concrete foundation, the latter can be made very satisfactory by letting concrete, mixed in the ordinary way, down a chute to the bottom of the excavation. To prevent the inflowing water from washing the cement of the concrete into the pump-well, the water should be allowed to rise to a convenient height so as to become calm with no applicable current towards the well. When good Portland cement or its equivalent is used, and the earth acts as a casing, it will be quite safe to commence building on the top of the concrete foundation twelve to eighteen hours after it has been made.

Before any masonry is started, the work should be carefully marked off. If the pier has a base with one or more offsets, as is usually the case, no great accuracy is necessary until the level of neat work is reached ; but if at any stage of the work below ground-level it is necessary to mark off the work, this should be done in accordance with some *one* convenient method. I have found the following process simple, rapid and reliable : A thin wire is stretched between two center line points, across the excavation ; and with a plummet this line is projected on the work below. The center of the pier is found by measuring along the center line the required distance from the nearest fixed points. This measurement can be accurately made with a steel tape held as nearly level as possible, on which the distance is read off and projected on the center line in the usual way. The pier can now be marked off with an ordinary wooden square and a straight edge.

Another way of marking the cross center-lines of the piers is to place stakes on both sides of the excavations and at right angles to the center line of the bridge, before work is commenced. But as these stakes are much exposed and likely to be disturbed during the progress of the work, they should be used only for marking off excavations, foundations, and such work as does not require any great accuracy.

A good centrifugal pump is very efficacious for drawing the water from the wells and excavations. As it occupies little space, is simple to erect, easy to move, and seldom gets out of order, it is more suitable for this kind of work than any other form of pump.

An easy-working, sliding suction and a simple, effective foot-valve are essential to a successful and economical management of the work. The sliding suction usually consists of a pipe or cylinder having a stuffing-box at one end and a flange for the foot-valve at the other. It is preferably made of sheet-iron so as not to be unnecessarily heavy. Inside this cylinder is placed a pipe of the same bore as the pump. The gland of the stuffing-box should run easily on the pipe, so that the cylinder may be moved freely up and down when the gland is loosened. A good foot-valve is made of an ordinary valve-chamber with an iron flap on hinges, moving freely, and with a leather edge to make a water-tight joint with the valve-seat.

It is very important that close and constant attention be given to the pumping machinery, as any interruption in the discharge of

the water will cause it to rise in the excavation, and when it is afterwards pumped out it is likely to wash down the material of the sides and entail considerable loss.

These remarks have been written with reference mainly to work on new railways. Other conditions will often suggest changes to be made in the methods of working, of obvious advantage.

PRECISE LEVELS OF THE MISSISSIPPI RIVER COMMISSION.

By R. J. Dickinson, '93, School of Civil Engineering.

It is the custom of the commission in the general survey of the river to run first precise levels, then triangulation, and lastly topography, the bench-marks of the levels serving as a basis for the subsequent surveys.

These benches are from 2 to 3 miles apart, and are mostly on the foundations of buildings, the piers of bridges, or natural ledges of rock; and are marked U. S. P. B. M. (United States Permanent Bench Mark). The exact point is the top of a small copper bolt, leaded into the rock. In case there are no buildings or natural ledges, the copper bolt is leaded into a hole in the center of a slab of vitrified fire-clay 18x18x5 inches, buried about 4 feet in the ground,and accessible from the surface through a 4-inch pipe. Besides these, temporary or ordinary benches are taken at the end of a stretch, usually about 1,200 meters apart. They are merely points of reference from one day to another, but are made as permanent as possible. Usually they are points on large embedded boulders or on foundations of buildings, or on spikes in the roots of trees.

The instrument used is what is known as the Swiss or Kern level. It has three leveling screws, an auxiliary tangent screw under one wye, a striding level with a radius of curvature of 380 feet, and three cross hairs for reading the rods. The latter are graduated to centimeters, and are read by estimation to millimeters and half millimeters. The rod is three inches wide, one inch thick, and three meters long, with a strip along the back to stiffen it.

Two rods are employed with each instrument, according to the method described in Baker's Leveling as System II.

The usual party is as follows: One instrument man or observer, one recorder, two rodmen, and two umbrella-men one of whom under ordinary circumstances serves as ax-man, and in case of thick underbrush or other like obstruction an additional ax-man.

The length of sight varies from 40 meters to 125 meters, the average being about 70 meters (230 feet) except in extraordinary cases, as, for instance, a river crossing, where sights are 200 meters (650 feet), or over, when a series of observations are taken.

The cost of these levels varies greatly with circumstances, and runs from $15.00 to $35.00 per mile. The average cost, however, is about $20.00 per mile. One reason why this is so high is that only six or seven hours per day can be utilized, on account of the tremulousness of the atmosphere in the middle of the day. From 5 to 8 or 9 a. m., and from 3 or 4 to 7 p. m. are the best hours of the day.

All stretches must have two lines run over them, and the results of these two compared. The limit of difference allowed is 3 m. m. $\sqrt{\text{dist. in kilom.}}$ (0.012 ft. $\sqrt{\text{dist. in miles.}}$)

The direct line between terminals is called the main line, and any other lines, such as connections with bench-marks, city datum, etc., are called the side line. In the work of 1891, between St. Paul and Savanna, a distance of 301 miles, there were 394 stretches in the main line and 300 in the side lines. Of these 694 stretches, 55 were run more than twice and 11 more than four times, on account of the results differing more than the allowed limit. The total length of the main line between St. Paul and Savanna is 486.09 kilometers. The probable error of the difference in elevation is 13.7 m. m., or 0.62 m. m. $\sqrt{\text{dist. in kilom.}}$ (0.0026 ft. $\sqrt{\text{dist. in miles.}}$)

The rate of progress for a double party was about 3,200 meters, or 2 miles, per day. The longest run made by a single party in a day was 5,600 meters, or about $3\frac{1}{2}$ miles.

RIVER GAUGING.

By Horace Dunaway, '89, School of Civil Engineering.

In the hydrographical survey of rivers, the problem of determining the water discharge is one which requires much time and care in making observations for the necessary data. If it is required to find out the amount of water passing a given point annually, these observations must extend over a year's time. If it is required to determine the discharge during extreme high or extreme low water, then the observations would terminate with any considerable change of stage.

In the improvement of the Mississippi river it is desirable so to construct levees and training walls that sufficient water may be furnished to maintain transportation during low water, and yet not so confine it as to cause damaging overflows during times of flood. For this reason it is necessary to know the amount of water passing certain points annually and at all stages from greatest flood to extreme low water. For determining this varying discharge three different methods have been employed on the Mississippi river and its tributaries. These methods are designated by the names, "Rod Floats," "Double Floats," and "Current Meter." The latter method, being considered the least liable to error, the simplest and the most inexpensive, is the one now generally used.

The current meter in use is the one invented and patented by W. G. Price, for a good description of which the reader may refer to the instrument catalogue of W. & L. E. Gurley. The number of revolutions of the meter wheel is recorded by an electric register, which is also connected with a chronometer and records the time on the same strip of paper ribbon, so that a full record of the number of meter revolutions, with the corresponding number of seconds, is obtained at each station for every observation. The paper ribbon for this record is one half inch in width and after being used has the appearance shown in Fig. 1, the dashes representing the inden-

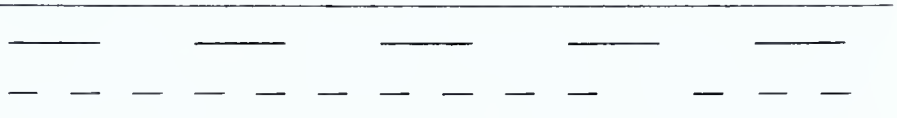


Fig. 1.

tures in the paper. In the upper line each long dash represents a half revolution of the meter wheel and the blank space the other half.

Similarly in the lower line each short dash represents a quarter second, and each blank space the same length of time. The chronometer is so arranged that every fifteenth half second is left unrecorded, leaving a long blank space to facilitate the counting of time.

For the purpose of making observations, a "velocity section" must be established and all observations taken at different points, called stations, on this section. In locating a section several important points must be considered. It should be at some place where the water is well confined by high and regular banks; and also where the river has practically a straight course for a considerable distance both above and below the desired place of observation. In order that eddies may not interfere, it should be at some distance from any large tributaries where waters of two streams are intermingling; if the waters were of unequal temperature, those of the warmer stream would rise to the surface, so that we might hav ea very slow under-current with a strong one at the surface or *vice versa*, according as to which stream had the more rapid descent above the junction. Here we might expect also to find the waters of the two streams running at an angle to each other, which fact would cause very serious trouble in observation readings. Should the direction of the current on opposite sides of the stream not be parallel, an angle may be made in the section, though evidently this would not be desirable.

Having selected a suitable section, normal to the current, necessary signals must be established for the location of velocity stations. The method generally used is to erect a line of signals on shore at right angles to, and up the river from, the section, the length of signal line being one fourth the width of the river and the signals being twenty-five feet apart. Points one hundred feet out on the section are located by means of a sextant set at an angle of 14°02′ (this being the angle in a right angled triangle such that the base is four times the perpendicular) read in the boat on an initial station on shore and the successive signal stations. Then every twenty-five foot space covered by the sextant, represents one hundred feet out on the section; or any fraction of twenty-five feet subtended by the sextant angle, corresponds to the same fraction of one hundred feet out from the river bank. But I think a better and simpler method is that shown in Fig. 2, which was used near New Madrid, Mo., in 1889, by Assistant Engineer E. L. Harman, on which work the writer also was employed.

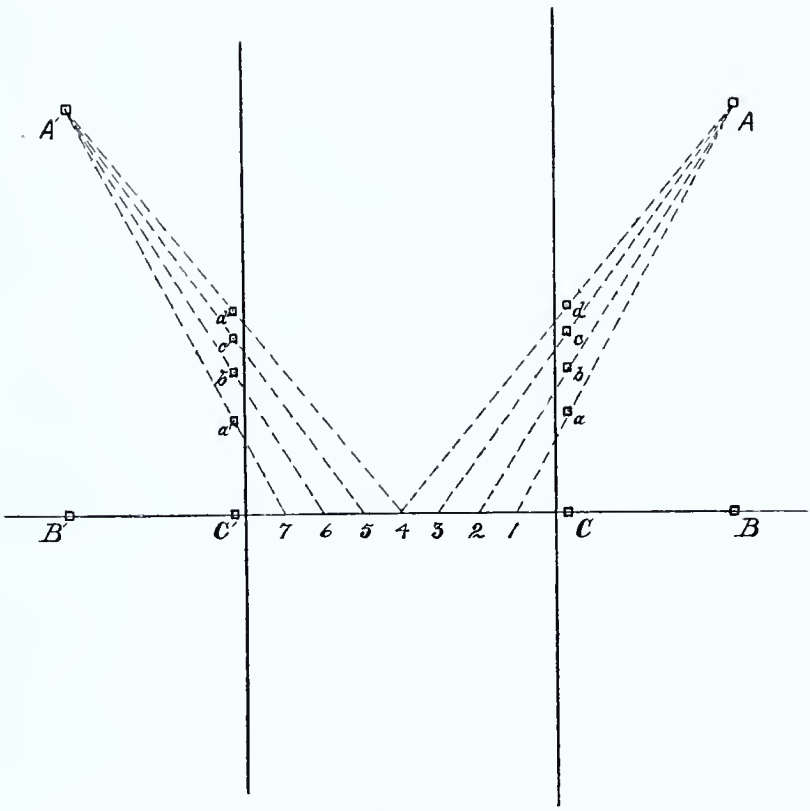


Fig. 2.

Establish points C and C' near the shore line and points B and B′ three or four hundred meters back, all being on the section line prolonged. The pivot signals A and A' are placed at any suitable points as indicated in the figure. Then having determined the number of velocity stations required, from the known triangles ABC and $A'B'C'$ calculate the direction of lines radiating from the pivot signals to pass through those stations ; and with transit set at A, turn off angles from B to intersect the sections at the required stations, as 1, 2, 3, etc., setting signals along the shore line at a, b, c, etc. All signals may be on the same bank, but with a wide river, it is less confusing to have two sets, one on each side and reaching half way across, as shown in the figure. For signals white cloths are fastened to the top of long, straight poles. If any confusion of signals is experienced, certain ones may be doubled or have different colored cloth.

Experiment has shown that the mean velocity of the current is at six tenths the depth of the water, and the meter is lowered to

that point for each observation. Soundings are made just before each observation, or the whole section is sounded first and the meter observations made immediately afterward. The former method is perhaps preferable, especially if the river is rising or falling, for a few inches in rise or fall may produce a greater scour or fill at the bottom. In making observations, a steam launch is generally used, though a large row-boat may answer the purpose where the current is not too strong. The launch being run to any desired station, as at 1, the meter is lowered into the water to the desired depth, while the steersman holds on line aA with bow up stream, and the engine-man keeps on line CB. After raising the meter the same operation is repeated at stations 2, 3, 4, etc., across the river. The meter being lowered from the stern of the launch by means of a pulley and derrick, and held from floating down stream by guy lines extending from the bow.

Great care is required in the rating of the meter. If still water can be obtained for this purpose, it is very desirable, though frequently this is not possible. To determine the rate, the meter is lowered into the water as at any observation station, and the launch passes back and forth a number of times, at different velocities, over a known base—say 300 feet in length.

Then if

a=constant to be determined.

b=the friction constant.

n=number of observations.

n_1=number of observations down stream.

n_2=number of observations up stream.

$\leq$=summation.

v=velocity of meter through space.

x=number of registrations per second.

x_1=meter registrations per second down stream.

x_2=meter registrations per second up stream.

y_1=meter velocity through space down stream.

y_2=meter velocity through space up stream.

y=velocity of meter through water.

z=velocity of water (supposed constant).

$y=v-z+b$ (meter down stream.)

$y=v+z+b$ (meter up stream.)

Therefore

$y=v+b=a\ x+b$, in still water.

The normal equations for finding the values of a and b, are as follows :

In still water,

$$a=\frac{n \lesssim (x\,y)-\lesssim x \lesssim y}{n \lesssim x^2-(\lesssim x)^2}$$

$$b=\frac{\lesssim x^2 \lesssim y-\lesssim x \lesssim (x\,y)}{n \lesssim x^2-(\lesssim x)^2}$$

Then

$$(n_1+n_2)\,z+(n_1-n_2)\,b+(\lesssim x_1-\lesssim x_2)\,a-(\lesssim y_1-\lesssim y_2)=0 \quad (1)$$

$$(n_1-n_2)\,z+(n_1+n_2)\,b+(\lesssim x_1+\lesssim x_2)\,a-(\lesssim y_1+\lesssim y_2)=0 \quad (2)$$

$$(\lesssim x_1-\lesssim x_2)\,z+(\lesssim x_1+\lesssim x_2)\,b+(\lesssim x_1^2+\lesssim x_2^2)\,a$$
$$-[\lesssim (x_1\,y_1\,y_1)+\lesssim (x_2\,y_2)]=0 \quad (3).$$

Equations (1) and (2) are simplified when n_1 n_2 are equal. The preceding equations are obtained by combining the separate observation equations, as follows :

For observation No. 1, $y_2=a\,x_2+b+z$ }
" " " 3, $y_2=a\,x_2+b+z$ } up stream (A)
" " " 5, $y_2=a\,x_2+b+z$ }

" " " 2, $y_1=a\,x_1+b-z$ }
" " " 4, $y_1=a\,x_1+b-z$ } down stream (B)

Subtracting the down stream equations (B) from the up stream equations (A) will give equation (1). Adding equations (A) and (B) gives equation (2). For equation (3), multiply each equation in (A) and (B) by the x in that equation and add the several results.

Where the rating is done in still water, the quantity z becomes zero, and only two equations are needed, in which case the equation obtained by substracting (B) from (A) may be omitted.

A good rating will require about eighteen or twenty observations.

On page 36 is the tabulated record of one day's observations and the computations for the same. Stations were 300 feet apart, and, as will be seen, two soundings were made between adjacent stations. These intermediate soundings were taken at points equally distant, by estimation, from the stations; points were estimated equal distance apart, so that from station 1 to station 20, soundings were made every 100 feet. Between each end station and the adjacent shore line, the depth was observed more frequently. Sta. I—201.2 feet represents the left shore line (see first column of table), and Sta. XX+204.7 feet is the opposite side of the river.

The direction of the wind is indicated by the clock-face method, XII pointing up stream and indicating a down stream wind. The remainder of the tabulation needs no explanation. It might be well to add that this set of observations is one of a series made during the extreme high water of 1890 and represents flood discharge.

Computation of Discharge of Mississippi River at *Watson's Landing, Ky.* Date—*April 10, 1890.* Gauge Reading, *15.48* feet. Width, *6,105.9* feet. Direction and force of wind, *N, brisk.*

Station.	Sounding.	Between Sd'gs.	AREA. Partial.	AREA. Registra'n.	Time.	PRODUCT. Partial Area × Registra'n.	Remarks.
	ft.	sq. ft.	sq. ft.		sec.		
I—201.2	0.0						
I—186.2	3.5	26					
I—151.2	14.0	306					
I—126.2	14.0	350	682	121.0	120	82522	
I— 76.2	27.5	1037					
I.	31.5	2248	6285	170.5	"	1071592	
	28.5	3000					
	29.5	2900					
II.	33.0	3125	9275	150.0	"	1391250	
	32.0	3250					
	31.0	3300					
III.	34.0	3400	10125	154.0	"	1559250	
	34.5	3425					
	39.0	3675					
IV.	36.5	3775	11000	162.0	"	1782000	
	34.5	3550					
	34.0	3425					
V.	33.5	3375	10525	157.5	"	1626187	
	37.0	3525					
	31.0	3400					
VI.	38.5	3475	10625	156.5	"	1662812	
	36.5	3750					
	37.5	3700					
VII.	35.5	3650	10925	145.0	"	1584125	
	36.0	3575					
	41.5	3875					
VIII.	39.0	4025	11725	169.0	"	1981525	
	37.5	3825					
	39.5	3850					
IX.	37.0	3825	11575	154.5	"	1788337	
	41.0	3900					
	40.5	4075					
X.	47.0	4375	13150	138.5	"	1821275	
	47.0	4700					
	47.0	4700					
XI.	45.5	4625	13750	168.5	"	2316875	
	43.0	4425					
	43.0	4300					
XII.	39.0	4100	12150	138.0	"	1676700	
	36.0	3750					
	38.0	3700					
XIII.	42.5	4025	12075	151.5	"	1829362	
	44.5	4350					
	42.5	4350					
XIV.	42.0	4225	12875	169.0	"	2175875	
	44.0	4300					
	43.5	4375					
XV.	45.5	4450	13400	164.5	"	2204300	
	46.0	4575					
	45.5	4575					
XVI.	45.5	4550	13775	186.5	"	2569037	
	47.5	4650					
	47.5	4750					
XVII.	47.0	4725	14275	152.0	"	2169800	
	49.0	4800					
	45.5	4725					
XVIII.	50.0	4775	14650	122.0	"	1787300	
	53.0	5150					
	52.5	5275					
XIX.	51.0	5175	15325	115.7	"	1773869	
	46.5	4875					
	45.5	4600					
XX.	41.0	4325	11644	98.0	"	1141112	
XX+75.	31.5	2719					
" +104.7	18.5	742	1468	63.0	"	92484	
" +169.7	2.5	682					
" +204.7	0.0	44					
			241079=Total area.			36,087,589	

Mean Velocity $= \frac{\text{DISCHARGE}}{\text{AREA.}} = 5.329$ ft. per sec.

$y = ax + b = 3.895x + 0.47$ total area.

$x = 36087589 \div 120 = 300730$

$ax = 300730 \times 3.895 = 1171343$

$b = 241079 \times 0.47 = 113307$

Total discharge in cu. ft. per sec $= 1284650$

TERRA COTTA.

C. J. Butterfield, '94, School of Architecture.

The great advancement in the manufacture of iron and steel and in its application to building construction has largely increased the demand for Terra Cotta. This material has had many vicissitudes, but is now admitted to be the best medium for ornamentation and is quite generally used as a substitute for stone.

It was first thought that terra cotta was not durable and would not stand exposure, but many tests have shown the contrary. Mr. Smith says, "Terra Cotta has been burnt to a white heat for at least two days. Heat and cold cannot again affect it. It is too hard to absorb moisture. Frost will not chip it in the winter, as it does stone carving. Being non-absorbent, it will keep its color forever, and not, like stone, suck in all the defilements of the atmosphere.

"If you take a piece of well-burnt terra cotta and soak it for a year in the sea, then burn it for a year in a furnace, then let it be frozen for a year with the thermometer at thirty degrees below zero, then tumble it down a mountain side, or drop it out of a balloon, and then examine it carefully and you will find it about the same as it was at the beginning, with the exception of an odd scratch or two on the surface, where it may have come in contact with a flint."

The ingredients of the clay used in the manufacture of terra cotta are:—alumina, silica, lime, magnesia, iron oxide, water, and a small per cent. of alkalies. To obtain different colors, some manufacturers use a mixture of clays, varying the combination to obtain the desired appearance which is sometimes light, or a soft buff color, at other times cherry-red or a hard brownish-red. The color obtained from rich clay varies from a light cream color to a soft buff. If oxide of iron enter abundantly into its composition, the terra cotta will be a dark red. Alkaline salts yield an efflorescence, which acts upon the silicates of the surface, vitrifying to a greater degree the exterior of the terra cotta.

The mixture of clays, and other ingredients, having been brought to a floury mass of the right consistency, it is formed in a mould, usually composed of several parts, into which it is pressed by hand. In making molds for intricate designs great care must be taken and experienced help employed. The plaster cast is covered with grease or soap, and then protected by a rubber cloth, on top of

which clay is placed to the depth of four or five inches, covering the surface of the cast. Against this, the backing of plaster is built which makes the backing of the mold. When hard enough, the plaster is removed and the rubber cloth and clay taken out, the backing of plaster being again replaced. The space between the model and the plaster, before occupied by the clay, is now filled with liquid gelatine. After about fourteen hours, the impression in gelatine is removed and placed upon the backing of plaster ready for reproduction. This process may be repeated five or six times on the same model without destroying the sharpness of the lines. The advantage in the use of gelatine is the accuracy of the reproduction. The yielding nature of the substance is especially adapted for under cut carvings and can be handled easily without fear of destroying the sharpness of the outlines. When the clay is drawn from the molds it is generally put into a drying room, which is especially adapted for this and which has good ventilation. Greatest care is exercised in the handling of these "green goods" as they are in a perishable condition before being returned from the kiln.

Kilns for burning terra cotta are generally circular in form, and are built expressly to obtain a greater degree and better distribution of heat. The application of heat in the burning is done by the overdraft system. In these kilns the heat is carried to the top through flues in the walls, and as the kilns are covered and the draft toward the bottom, the heat descends through the pieces. In this class of kilns, the pieces are not so liable to twist, warp, or crack. The advantage of the circular kiln is the equal distribution of heat, thus producing a uniformity of color so much desired. One of the hardest colors to obtain uniformly is the so much admired soft buff color. Wood fuel must be used and the clay well burned. For red and dark-colored ware, coal is not objectionable.

During the process of drying, the terra cotta will lose about one twenty-fourth of its bulk and one-twentieth of its weight, and this shrinkage continues during the process of burning, which lasts from five to seven days. At the end of these processes, the total contraction is about one-twelfth, and the reduction of weight about one-fourth. If the size of the piece be moderate, it will shrink without cracking or distortion, and with but small risk of failure. The surface is also affected, since unequal drying causes varied contraction, which the light of the sun apparently magnifies. For this reason, terra cotta should never have a smooth finish for exterior work.

Many treatments of the surface are in vogue as toothed, combed and crinkled finish, all of which are used to convey the idea of a soft, plastic material.

As a rule, all building materials are carefully inspected before using, and terra cotta should be no exception. The point of a steel instrument should not pierce the surface, and is a good test of its texture. If through contact with the ware, the point should strike fire, all the better. A sharp, metallic, bell-like ring, and a clean, close fracture are good proofs of compactness and strength.

The modern architectural uses for terra cotta are for balusters, bases of columns and pilasters, belt courses, capitals, columns, copings, cornices, friezes, mouldings, newels, niches, panels, pedestals, skew-backs or springers for arches, string courses, tiles, window heads and mullions.

It is sometimes considered as very light in weight, but this is only true in regard to the pieces when shipped, for when set in place and properly filled, to protect the crevices from water, it has the same weight as brick work, and all large projections and openings should have a backing framework of iron.

The shade of color, which is so essential to good artistic effects, is very hard to duplicate and is unreasonably demanded. There is said to be no objection to the use of paint, and as lead paint lasts longer on terra cotta than on either wood or iron, why should we not give the artist a chance to produce the desired effect? A thorough study and knowledge of the uses and applications of terra cotta by the architects of to-day would do much to raise the standard of artistic effects and would probably create the so much desired American Order of Architecture.

LEAD REVERSIBLE BATTERIES.

By B. V. Swenson, '93, School of Mechanical Engineering.

The secondary, or, as it should rather be called, the reversible battery, dates practically from the discovery that electric currents could be produced by the agency of chemical action, and its development progressed with the increase of our knowledge of the laws which govern electrolysis.

It was not till Faraday's discovery of the laws relating to the conversion of mechanical into electrical energy, and of a cheap source of electricity, that much attention was paid to reversible batteries.

In 1859 Plante made a number of experiments with copper, silver, tin, lead, aluminum, iron, zinc, gold, and platinum voltameters, to discover which was the best couple to use for a reversible battery, and in March 1860, he decided on lead plates in dilute sulphuric acid, because in discharge both plates were active, that is, not only did the peroxide of lead plate combine with hydrogen, but the reduced metallic lead plate combined with oxygen. Thus the E. M. F. of the cell was due to chemical actions occurring on both plates. In those days the action of the cell was ascribed solely to the decomposition of water and the effect of the sulphuric acid was left out of account.

In 1872 Plante improved the "formation" of his cell by introducing the process for alternate reversals of the current. In the decade which followed, with the improvement of the dynamo and the consequent growth of electrical engineering, the need for some means of storing electrical energy arose, and the reversible battery passed from laboratory into general use.

In 1880 M. Camille Faure invented his cell, in which the electrodes consisted of lead plates smeared with pastes of red lead and litharge respectively, and covered with a protection of felt. On charging, the red lead was oxidized to peroxide of lead, and the litharge was reduced to metallic lead, thus forming a couple of considerable storage capacity. The immediate results obtained with the Faure system deeply impressed electricians. The mode of supporting the active materials by means of felt partitions had to be abandoned, but the principle of heterogeneous formation, by the addition of oxides, still remains in use. The lead grid now came into use, and consisted simply of a lead grating as light as

possible, which supported some form of lead oxide, the electrolyte consisting of dilute sulphuric acid.

The tests from which the data of this article were obtained, were made upon a battery of twenty-six cells, of the common lead grid Faure type. The positive plates were pasted with red lead and sulphuric acid, and the negative plates with litharge and sulphuric acid. For the latter water would answer the purpose, but the paste thus obtained would not be so coherent. The number of plates in each cell was nine, four being positive and five negative, and these were arranged alternately. The number of negative plates is always the greater in these cells, as the chemical reactions require more litharge than red lead. The plates were about six by eight inches, that is, about 48 sq. ins. of surface, and as each plate has two sides the total active surface per plate would be about 96 sq. ins.

The proper limit of current for charging this kind of cell is 5.3 amperes per square foot of positive plate. The limit for discharge is greater, but should not exceed 6.1 amperes per square foot of positive plate.

The chemistry of the cell is not as yet thoroughly understood. The positive plates when formed with $H_2 SO_4$, make lead sulphate, $Pb SO_4$, and the negative plates remain litharge, Pb O.

The reactions are probably as follows, according to Sir David Salomons:

	POSITIVE.	ELECTROLYTE.	NEGATIVE.
1st	stage—$Pb SO_4$	$H_2 SO_4 + H_2 O$.	Pb O.
2nd	" —Pb O.	"	Pb O.
3rd	" —$Pb O_4$	"	Pb.

The first stage indicates the discharged cell.

In the second stage, a molecule of $H_2 O$ has been removed from the electrolyte, and one of $H_2 SO_4$ has been added, thus increasing the strength of the acid solution, which remains unaltered in stage three, and thus we see why the specific gravity of the electrolyte increases as the charging advances.

The chemical actions are probably far more complex than those given above, but in general the explanation is fairly correct.

According to the researches of E. Frankland, DCL., FRS., the chemical actions expressed as formulæ are as follows:

1st—Reaction of litharge and sulphuric acid.

$$5\ Pb\ O + 3\ H_2\ SO_4 = \underset{\text{Buff lead salt.}}{S_3\ Pb_5\ O_{14}} + 3\ H_2\ O.$$

2nd—Reaction of minium and sulphuric acid.

$$Pb_3\ O_4 + 2\ H_2\ SO_4 = \underset{\text{Red lead salt.}}{S_2\ Pb_3\ O_{10}} = 2\ H_2\ O.$$

It is not definitely known which of these plates is the active material during the chemical action which takes place in charging and discharging. But if the buff lead salt is considered the active material, we have the following reactions during charging:

POSITIVE PLATES.

$$S_3\ Pb_5\ O_{14} + 3\ H_2\ O + O_5 = 5\ \underset{\text{Lead peroxide.}}{Pb\ O_2} + 3\ H_2\ SO_4$$

NEGATIVE PLATES.

$$S_3\ Pb_5\ O_{14} + 5\ H_2 = 5\ Pb + 3\ H_2\ SO_4 + 2\ H_2\ O.$$

For discharge:

POSITIVE PLATES.

$$5\ Pb\ O_2 + 3\ H_2\ SO_4 + 5\ H_2 = S_3\ Pb_5\ O_{14} + 8\ H_2\ O.$$

NEGATIVE PLATES.

$$5\ Pb + 3\ H_2\ SO_4 + 5O = S_3\ Pb_5\ O_{14} + 3\ H_2\ O.$$

If the red salt be the active material, the reactions would be during charging:

POSITIVE PLATES.

$$S_2\ Pb_3\ O_{10} + O_2 + 2\ H_2\ O = 3\ Pb\ O_2 + 2\ H_2\ SO_4.$$

NEGATIVE PLATES.

$$S_2\ Pb_3\ O_{10} + 4\ H_2 = 3\ Pb + 2\ H_2\ SO_4 + 2\ H_2\ O.$$

For discharge:

POSITIVE PLATES.

$$3\ Pb\ O_2 + 2\ H_2\ SO_4 + 2\ H_2 = S_2\ Pb_3\ O_{10} + 4\ H_2\ O.$$

NEGATIVE PLATES.

$$3\ Pb + 2\ H_2\ SO_4 + 2\ O_2 = S_2\ Pb_3\ O_{10} + 2\ H_2\ O.$$

From these formulæ, the deduction is drawn that in the case of the red lead salt, only one half as much active material is electrolytically decomposed on the negative plate as on the positive, and this is substantiated in practice.

The cells used in this experiment had been set up but a short time, and had only been charged and discharged twice ; but the first charge was light, so that practically this was only the second good charge which had been given them. In the first charge no data were kept. In the second the efficiency was found to be 45.7%, while in this test the efficiency is 72.72%, which is a little better than can be expected in common use.

One thing which is shown in the data given in this article, and

which frequently puzzles the users of cells, is worthy of mention. When a new battery is erected, on its receiving a considerable charge the specific gravity of the electrolyte is found to rise which is usually the case. But after standing a few days or even hours, this increase of specific gravity is partly, and sometimes even almost wholly lost; a state of things which may continue for many chargings. When this does occur it is a proof that the plates have not, as yet, been fully formed,and that chemical action continues within the plates while the battery is standing. The opposite effect is produced upon discharging.

The voltage, in all cases, seems to rise and fall with the specific gravity, yet no disadvantage is attached to this phenomenon.

For charging the batteries a 110-volt incandescent machine of 35 lights capacity was used.

CHARGE.

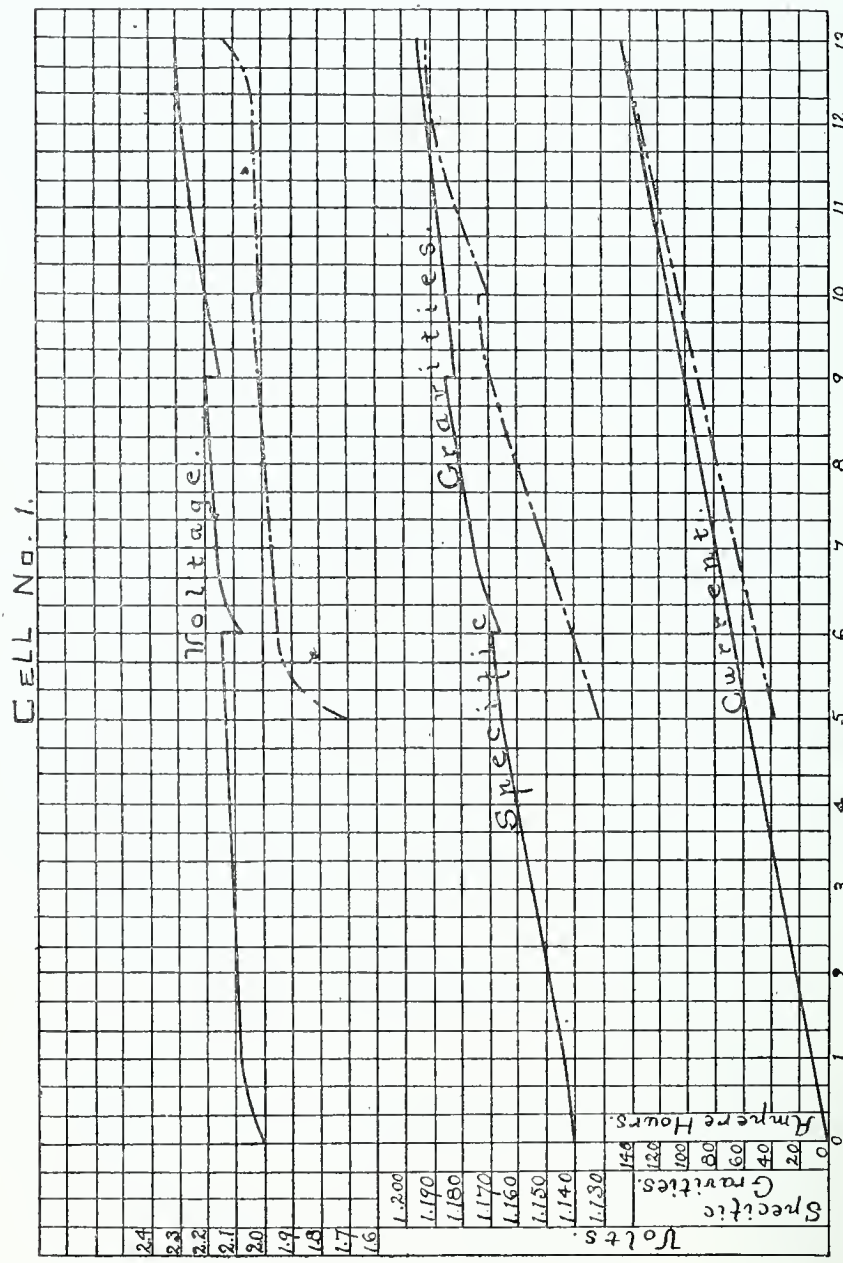
	VOLTAGE.				SPECIFIC GRAVITY.			
CELL NO.	1	5	12	26	1	5	12	26
Start	2.00	2.00	2.00	2.00	1.140	1.144	1.142	1.140
End 1st hour	2.08	2.10	2.09	2.10	1.143	1.146	1.145	1.144
" 2nd "	2.09	2.11	2.10	2.11	1.149	1.152	1.154	1.152
" 3rd "	2.11	2.13	2.12	2.12	1.155	1.170	1.160	1.160
" 4th "	2.12	1.14	2.13	2.13	1.160	1.176	1.166	1.168
" 5th "	2.13	2.15	2.14	2.14	1.166	1.178	1.176	1.176
" 6th "	2.15	2.17	2.15	2.15	1.169	1.186	1.186	1.180
Begin. 7th hour	2.07	2.08	2.07	2.07	1.166	1.184	1.184	1.176
End 7th hour	2.16	2.19	2.17	2.17	1.175	1.186	1.186	1.181
" 8th "	2.18	2.20	2.18	2.18	1.180	1.190	1.190	1.185
" 9th "	2.20	2.28	2.20	2.20	1.184	1.197	1.194	1.190
Begin. 10th hour	2.14	2.16	2.12	2.12	1.182	1.195	1.192	1.188
End 10th hour	2.20	2.30	2.20	2.20	1.184	1.200	1.198	1.193
" 11th "	2.25	2.30	2.21	2.21	1.188	1.202	1.200	1.198
" 12th "	2.28	2.31	2.22	2.22	1.192	1.205	1.204	1.204
" 13th "	2.30	2.32	2.22	2.22	1.194	1.210	1.209	1.209

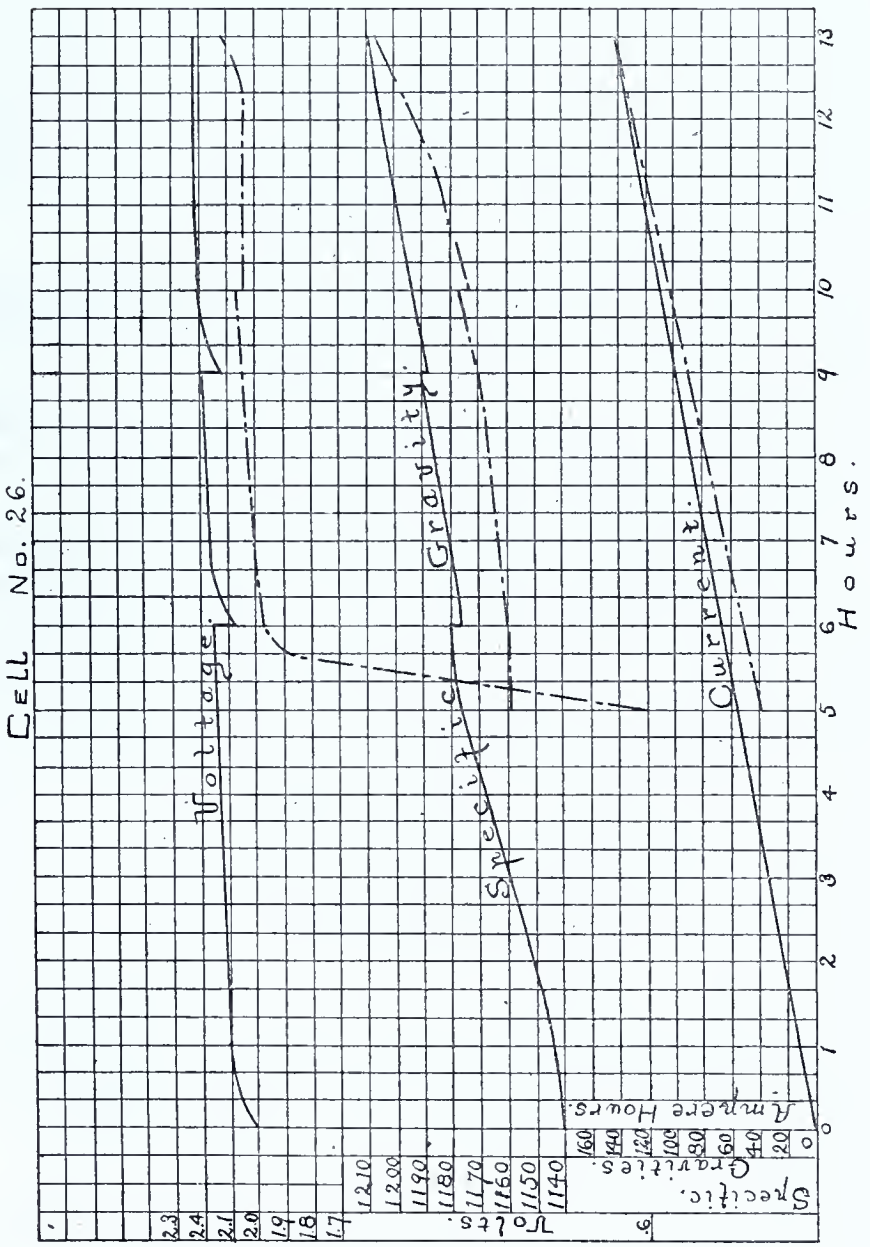
The charging current was constant at eleven amperes.

DISCHARGE.

	VOLTAGE.				SPECIFIC GRAVITY.			
CELL NO.	1	5	12	26	1	5	12	26
Started	2.14	2.14	2.12	2.12	1.192	1.208	1.207	1.207
End 1st hour	2.03	2.04	2.05	2.05	1.189	1.202	1.204	1.194
" 2nd "	2.02	2.03	2.03	2.05	1.181	1.195	1.201	1.182
" 3rd "	2.01	2.03	2.03	2.05	1.170	1.190	1.198	1.170
Begin. 4th hour	2.03	2.05	2.05	2.06	1.173	1.192	1.201	1.173
End 4th hour	2.01	2.03	2.03	2.04	1.168	1.182	1.192	1.166
" 5th "	1.98	2.02	2.02	2.03	1.160	1.174	1.183	1.164
" 6th "	1.97	1.98	1.95	2.00	1.150	1.164	1.176	1.160
" 7th "	1.95	1.95	.70	1.95	1.141	1.152	1.172	1.159
" 8th "	1.80	1.80		.60	1.132	1.149		1.158

The discharging current was constant at thirteen amperes.


CELL No. 1.
Voltage.
Specific Gravities.
Current.
Volts.
Specific Gravities.
Ampere Hours.
Hours
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.200
1.190
1.180
1.170
1.160
1.150
1.140
1.130
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13


Cell No. 26.
Voltage.
Specific Gravity.
Current.
Hours.
Volts.
Specific Gravities.
Ampere Hours.
2.3
2.4
2.1
2.0
1.9
1.8
1.7
1210
1200
1190
1180
1170
1160
1150
1140
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13

The cells having a counter electro-motive-force of about fifty-five volts, the voltage above that of the battery was about fifty-five volts also, which was the voltage of charging.

A Weston ammeter and voltmeter were used. Four cells out of the twenty-six were selected at random, from which data were obtained, and two of these sets of data were selected for a graphical representation of the cells during charge and discharge. In the graphical representations the voltages and specific gravities are different for each cell, but as the cells were in series when charged, the current would necessarily be the same for each cell.

Readings were taken every hour, the current being thrown off when the voltage was taken. And whenever a stop-over was made each cell was disconnected at the switch-board from every other cell so that no action between cells could occur.

The first six hours of the charge was continuous. Between the sixth and seventh hours, and also between the ninth and tenth hours, a stop over night was made.

In discharging, a number of 50-volt 16 c. p. incandescent lights were used for resistance in connection with a variable resistance consisting of 30 one tenth ohm coils, made of very heavy iron wire. The Weston ammeter was used in registering the current, and a constant current of 13 amperes was discharged for eight hours. The charging cement consisted of 11 amperes for thirteen hours.

$$\text{Efficiency} = \frac{\text{ampere hours discharge.}}{\text{ampere hours charge.}}$$

Therefore, $$\text{Efficiency} = \frac{8 \times 13 \text{ ampere hours.}}{13 \times 11 \text{ ampere hours.}}$$

And the efficiency is 72.72%.

In discharging, a stop over night was made between the third and fourth hours. In discharge the voltage runs along very nearly the same until the cell is about discharged. When the cell has nearly reached the point of exhaustion, the E. M. F. falls very rapidly.

All lead reversible batteries give a voltage of "two" or a little over. The proper time to cut out a cell from the circuit is just when its E. M. F. is *beginning* to fall rapidly, which in these cells is about 1.8 or 1.9 volts.

It will be seen from the data that cell number twelve did not

last through the entire discharge, and also that eell number twenty-six was falling rapidly and had gone beyond the proper limit.

The internal resistance of storage cells is very seldom stated, and then generally only approximately. In measuring the internal resistance, the "condenser method" was used. Two measurements were made, one of a single eell, and the other of the whole battery together with the conneetions of the eells to the switch board.

A one third micro Farad Standard Condenser, a "Legal" ohm resistance box, and a Thompson square pattern galvanometer, were used in making these measurements.

The internal resistanee of a single eell was found to be .0247 ohms, while the resistanee of the whole battery was 2.847 ohms. The resistance of the conneetions would be the difference between the resistance of the whole battery and the internal resistance of the twenty-six cells, or 2.2048 ohms.

The great problem now with the lead reversible battery is how to reduee the weight of the cell without injuring it. Because of its high E. M. F. and effieiency, it is the best storage eell yet devised, and if it were somewhat lighter it would be in great demand for street railway power, and other uses of a similar nature.

JAPANESE TEMPLE ARCHITECTURE.

By Shigetsura Shiga, '93, School of Architecture.

What Greeee owed to Egypt, Phoenicia and Assyria, Japan owes to Corea, China and India. The early eivilization of Japan was undoubtedly derived from the three nations above mentioned, for if we traee the literature, art, and seienees, which existed at an early period in Japan, to their origins, we find them in the majority of cases, among these three nations. At the time when the Persian invaders were totally defeated by the Greeks, and the latter were hurrying the eonstruetion of monuments and temples, Japan had not yet eome into eontact with either China or Corea. The rulers as well as the subjeets were enjoying the log-hut, in primeval state. The purest

typical building of this time, now over 1,200 years old, is still to be seen in Nara, in the province of Yamato.

In all nations and all ages of antiquity, the temples are the most important and the most interesting buildings, so in dealing with the architecture of any nation, the first attention of an observer is given to the religious buildings of the country. The object of my theme is to set forth a general idea, or the general characteristics, of the temples in Japan, but since temples as well as other buildings are subject to the influence of the religion, manners and customs of the people, also the climate and nature of the country, allow me to speak briefly on these points first.

About 700, A. D., Buddhism was introduced into the country through China. At first it only converted the royal families and nobles, for they at that time were the best educated class of the people. Soon after it spread all over the empire with overwhelming power; huge temples were erected; priests and monks were highly honored; which finally made the temples the seat of learning. Its doctrine, being purity of life and benevolence of mind, did not contradict, in some respects, the original native religion called Shintoism, which teaches simplicity and purity of mind and body. The simplicity of Japanese residences is surely affected by this religion. The Buddhist who is taught the successive transmigration of human beings, from the past to the present, and from the present to the future, carrying the idea of benevolence to an extremity, will not destroy even an insect or injure any animal in creation. This idea, it seems to me, has instilled the Japanese artists with a love of nature. Beasts, birds, insects and flowers in different combinations are subjects of carvings, reliefs, and paintings. I do not assert, however, that love of nature in general owes its origin to Buddhism, but more or less so in Japan. Buddhism in Japan is divided into eight sects, and these are subdivided into several smaller sects, some of them entirely spiritual, and others, utterly idolatrous. Notwithstanding the difference of principle in the two religions, they work in such perfect harmony that one could be a Shintoist and Buddhist at the same time; a peculiar circumstance, indeed!

As Shintoism in one sense is a sort of hero-worship, there are as many gods as heroes, and not only heroes are worshiped, but very old trees, mountains, valleys, and all kinds of natural objects. To the mind of the good-natured Japanese country rustic, Nature over-

flowed with deities. We find here, a good deal of similarity to the early Greeks; they had an idea that every grove had its presiding genius, every stream and fountain its protecting nymph Earth and air were filled with invisible spirits, and the sky was crowded with translated heroes.

Writers on Japan have pointed out in many cases a likeness between the manners and customs of the Japanese and ancient Greeks, and a writer in the Cosmopolitan mentions numerous resemblances between the ways and traits of the modern Spaniard and Japanese. This is not the proper place to dwell upon such an irrelevant subject, but according to my observation concerning the manners and customs of the "Land of the Rising Sun," it is quite surprising to note that the modern Japanese and ancient Greeks resemble each other so much that if a change of a few words were made in the description of certain customs and manners of theirs, the same expression would be precisely applicable to the Japanese.

Climate in Japan is almost the same throughout the country, the average temperature being about 50 degrees. From May to June they have constant rain, followed by intense heat until August. Rain falls more or less throughout the year, and there is plenty of snow in winter in the northern part.

The country is very rich in woods; all mountains which extend longitudinally from North to South are covered with trees. Rivers are abundant and give the best opportunity for transportation of lumber. The climate and soil are particularly favorable to the growth of trees, and the people are very careful not to cut down any kind of tree unless they find a special use for it.

The woods which are used for constructive purposes, especially for temples, are as follows: Keyaki (*Zelkawa keaki* Sieb.) is used chiefly for columns, beams, etc., of temples and other important buildings. It is nearly always used for massive structures. Cherry, oak, persimmon, camphor-wood, and white mulberry, are used for the doors, windows, furniture and joinery of temples. White pine, cedar, and paulownia, are used for residences and Shinto temples.

Buddhist temples in Japan are all of about the same plan, consisting of main building, gateways, treasuries, and small cells. Characteristic of the structure of the temples are their ponderous, heavy concave roofs, of very steep pitch. It is covered by rows of black tiles, the lower end of each row decorated by circular ornaments in which a uniform design is cut in relief. The ends of the

ridge of the roof are also decorated with several designs cut in relief, bearing the arms of a family, if the temple has been dedicated to a certain family. This style of roofing might have been derived from China; the same thing is also to be seen in the Island of Java, and it somewhat resembles that of the temple of Jupiter Olympus at Athens. The long, ogee-shaped roofs, which are common in temples, might have been suggested by the Dravidian style of architecture, which includes that of all southern India.

The way of laying tiles was a very singular one; the horizontal, massive keyaki beams support web members and tie beams, purlines and rafters. The rafters are concave and project to a considerable distance from the wall line, and all visible parts are decorated with black lacquer. Upon the rafters very thin shingles were laid and then covered by clay; upon this clay the tiles were placed, sometimes being kept in position by the use of large nails driven through the tiles into the rafter, so that the roof of a temple must have been exceedingly heavy.

Mouldings were very rarely used in temples, high relief wood carvings of designs of waves, animals, flowers, birds and plants, being substituted for them. Different patterns were employed for mouldings, the "Greek" or "Greek Key" patterns being frequently used on string courses and girders.

There is no portion of the temple which we can properly call a pediment. Its place was decorated with curious shapes of wooden carving. The horizontal beams, which were usually decorated with lacquer or sometimes by reliefs, were upheld by compound brackets, which were joined one upon another. In the famous gateway in Nikko, hundreds of thousands of brackets were used, all carved and painted.

The gateways of temples are of two forms; one is merely a gate, the other is a gateway with a gallery over it. The gallery itself is supported by bracket work which is similar to that which supports roofs. The railing of the gallery is decorated with metal.

There is nothing that we could properly call a capital in Japanese temples, except perhaps the lion capital, which might have been derived from either Buddhist architecture in India, or bull-head capitals in Greece. The bracket work takes the place of the entablature, architrave and capital of the Greek order. Columns are diminished, but oftentimes they are simply cylindrical, decorated with diaper-patterns and dragon reliefs, and treated with masterly skill. The

columns in the Nikko temple are not diminished, but those of temples at Nara, which were erected twelve hundred and eighty-three years ago, shows considerable diminishment. The lotus capital which decorates the columns of the great temple of Karnak is also to be seen at the bottom of web members of a temple in Kioto.

The Nikko temple is dedicated to the Shogun family; it was erected in the 17th century by the aristocratic Shogun government. It contains about one hundred and eleven cells, shrines, gateways, and pagodas. That was the golden age of fine arts in Japan, when it was designed, it is the place where once the artist spirit of the age was concentrated. The plan and details of this temple have not been published, so these facts are not well known. Most careful and delicate work was wrought in each building. Dresser says of one of the gateways: "The elaboration of detail in this gatehouse is absolutely indescribable. There must be thousands of brackets supporting the gallery alone, while as many are employed in sustaining the roof. Here we have dragons in full relief by the score, kylins in almost every attitude, carved flowers, groups of figures, clouds, water, diaper-patterns, and ornamental compositions wrought by the chisel, drawn by the brush, or hammered up in metal; while the whole constitutes a mass, beautiful in its proportions, pleasant in its 'quantities,' correct in its structure, and a very world of color harmony. This is the most marvelous architectural work that I have ever seen, and days might well be spent in considering it."

The most noticeable feature in Japanese temples is the delicate bronze and brass work which decorates the terminations and angles of girders and beams, and the ornamentation of the whole mass by lacquer, which is a special production of the Japanese. The use of metal for structural purposes is of comparatively recent date, even in civilized countries. Iron construction is quite a new subject in Japan; a suspension bridge which was built about twenty-five years ago, in the imperial garden in Tokio, may have been the first use of iron for such purposes, but the use of metal in ornamental work is of ancient origin. All the frame work of the windows and doors in temples is decorated with repousse work of silver, copper, bronze, or brass. Every important part of beams and girders, where the members are joined together, is covered by a peculiar form of repousse work.

The coloring material of temples is uniformly lacquer, in which the Japanese displayed their manipulative excellence. It offers but

the primitive colors, as these only can be applied. As to its manufacture and the preparation of colors, there are several processes, which are monopolized by their inventors and kept secret. It is said that this work had its origin in Corea. Whatever its derivation may have been, it was perfected by the Japanese. Lacquer work in Japan flourished most in the 17th and 18th century, and the Nikko temple is the production of this era. The whole temple is a tremendous mass of lacquer work. As the work needs great care in its execution and the utmost caution to prevent cracking, great patience is necessary to finish it, and it is consequently very costly. A certain English lady, as the story goes, paid gold in equal quantity for goods of this material. The permanence of Japanese temples, some of which have stood for over two hundred years, may be due to their coating of this material.

Stone masonry was not used for building material, except for the walls and floors of the temples, though sometimes it was used in bridge construction making arches in successive spans. It seems to me that the fear of using stone in construction was caused by the frequency of shocks of earthquakes, which are most dangerous to stone work. As a whole, Japanese temples seem to be too massive and to have too lavish a use of wood, but it may be necessary to do this in order to preserve the equilibrium of the whole mass. From this point of view the principle of construction of the Japanese temples becomes clear.

Plaster was used from an early time. As wall paper was not extensively used, peculiar color effects were secured for walls by mixing various colored sands into the plaster; this is mostly used for residences. For temples, only white or dead black walls were used. Bases of walls enclosing temple grounds were constructed of cyclopean masonry without mortar, and both sides of the walls were sometimes battered. Their top was always protected by tiles, forming a small gable with dark shaded projecting eaves.

Rock-cut temples, which were very common in Western Europe, India, and China, are never seen in Japan so far as I know. Occasionally we find small cells or shrines for deities. These may interest the archaeologist, but they are not worth while to be considered as specimens of architecture. We must not forget that the colossal statues or lions which were common in Western Europe and Central Asia are also to be seen in Buddhist temples in Japan.

The faith of old Japan being Shintoism, its temples are

exceedingly simple, the materials being wood and thatch, and no tiles were used. The characteristic of Shinto temples is the *torii*, which is the simplest and purest form of frame work of a gateway. Another characteristic is the spindle-like bodies, which, differing in length according to the size of the temple, cross each other in × shape upon the ridge. "The great symbol of Shinto is a mirror; for, just as a mirror reflects our image, so, symbolically, Shinto is to be considered to reveal our innermost actions, or to reveal our innermost heart." This mirror is placed in the back part of the main cell. The symbol itself is simple, so also the construction of the temple, cylindrical or square uprights, finely dressed, set on a carefully laid foundation. A gallery which is accessible by a flight of steps surrounds the main building seven or eight feet above the ground. Upon the uprights large beams are laid, supporting rafters, whose ends form large eaves. The metal repousse work is only an ornament of Shinto temples. It is simple, in harmony with the general spirit of simplicity, which produces a deep impression of reverence in the worshippers.

One point is to be noticed particularly in Japenese temples, no matter where they are placed. The site of the building is quite picturesque; the surrounding garden is like a park. Isolated from the busy life of the town, it gives a better effect to the temple, and a better opportunity for repose to the restless mind.

On the whole the ancient Japanese as engineers were like children, when compared with the Romans; as decorators or artists they stand side by side with the Greeks; but the tender ideas of the love of nature were revealed in carvings instead of sculptures, and more stress was laid on beauty and careful workmanship than on the grandeur and magnificence of the buildings.

Although the metal casting executed in Japan for ornamental purposes has greatly attracted the attention of European artists since the International Exhibition in France, and the last Vienna Exposition, their wood carving is not very well known. Fancy work on balconies and cornices of frame houses in this country has became quite prevalent in the past few years. Why cannot carved work with finely chiseled out birds, plants and animals, like that which decorates every part of the temple at Nikko, be adopted in the decoration of frame buildings in this country? I have noticed the idea already used in terra cotta designs, and I believe that the time will come when I shall see a finely carved ceiling, such as that of the great

temple, decorating the hall of a society or the parlor of some palatial dwelling in the United States.

Since the introduction of Western civilization in their country, the Japanese architects have been so busy building houses of European style, that the study of the invaluable works of the temples has been almost entirely neglected. As very few American and European architects have an opportunity to peep into the great temples in Japan, the work of enlightening the architectural world concerning these masterpieces is left for the young men of Japan.

TEST OF THE ENGINE AND BOILER OF THE ELECTRICAL LABORATORY.

By W. A. Martin, '92, and W. Snodgrass, '92, School of Mechanical Engineering.

The data of the following paper are taken from one of a series of tests on the engine and boiler of the electrical laboratory. The engine is one of the two engines in the dynamo room, and the boiler is in a separate building, which contains other boilers used for heating purposes. There is a Stratton steam-separator in the steam pipe 6 feet from the engine. It is made automatic in its working by means of a steam trap connected to the drip pipe. The exhaust steam is returned to the boiler-house, where it passes through a Baragwanath feed-water heater. For convenience the description of the tests are given separately.

Engine Test.

The engine is the Ideal, manufactured by the A. L. Ide Co., of Springfield, Ill. It is rated at 50 horse power when set to run at 300 revolutions with 80 lbs. of steam. The engine and boiler tests were made at the same time. On account of the flange of the belt wheel being slightly deeper than that of the governor wheel, the brake was applied to the belt wheel and the flange utilized to hold the water to cool the wheel. The brake was of the ordinary Prony pattern, with blocks 3×9-in. and held together by a $\frac{1}{8} \times 3$-in. wrought iron strap. It was lubricated by two oil cups supplied with good heavy engine oil, and also by lard applied from time to time with a small paddle. The water was supplied by means of a $\frac{1}{2}$-in. pipe reduced to $\frac{3}{8}$-in., and this made slightly smaller form to a $\frac{5}{16}$-in. nozzle. The $\frac{3}{8}$-in. pipe

was bent to follow the curve of the wheel so that the high rate of speed of the wheel would not spatter the water away from the rim. For an outlet a $\frac{3}{4}$-in. pipe was filed to a sharp edge, and flattened on one side, and placed on the opposite side of the wheel from the inlet, where it scooped out the water. On account of the shallow flange and the small place left at each side of the balancing weight attached to the rim, it was difficult to keep the wheel cool after running for a few hours with a heavy load. The centrifugal governor worked efficiently. The reducing motion for the indicator was formed by screwing a standard to the cross-head and connecting with a pantagraph fastened to the floor. The two ends of the cylinder were connected with the indicator by a three-way cock. The tests were made in the usual way.

The areas of the indicator cards were measured with a planimeter and the indicated horse power calculated by the well-known formula H.P. $= \frac{2\,R\,A\,S\,P}{33{,}000}$. The brake horse power was found by the formula H.P. $= \frac{\text{Speed of pulley rim} \times \text{Pull on rim}}{33{,}000}$.

The boiler and engine are connected by 125 ft. of $3\frac{1}{2}$-in. pipe, containing seven bends. On account of the long distance and the number of turns in the pipe the steam pressure would have to be carried at 110 lbs. at the boiler to get the full rated power from the engine.

The results of the test are shown in Table I and by the plate of sample indicator cards. Fig. 1 is for the lightest load applied, and Fig. 4 for the heaviest. The efficiency of the engine is the ratio of the brake horse-power to the indicated horse power, and was found to be 82.2%. The ratio of engine friction to indicated horse power is larger in Table I than the average found from several tests we have made. The average engine friction from the series of tests is 14.4%.

TABLE I—ENGINE TEST.

CARD NUMBER.	Boiler Pressure.	Revolutions of Engine.	Mean Effective Pressure.	Indicated Horse Power.	Initial Pressure.	Boiler less Initial Pressure.	Brake Weight.	Brake Horse Power.	Engine Friction H. P.
1	97	300	11.29	13.43	73.5	23.5	34	10.20	3.23
2	98	298	22.41	26.48	76.5	21.5	74	22.05	4.43
3	97	293	31.33	36.41	74.5	22.5	114	33.40	3.01
4	100	292	42.97	49.74	80.0	20.0	136	39.71	10.03
5	106	292	44.15	51.12	83.0	23.0	136	39.71	11.41
6	103	295	41.79	48.90	82.0	21.0	136	40.12	8.78
7	75	290	34.38	39.54	55.5	19.5	104	30.16	9.38
8	106	296	38.76	45.49	81.5	24.5	136	40.25	5.24
AVERAGE.	97.7	294.5	33.38	38.89	75.8	21.9	108.5	31.95	6.94

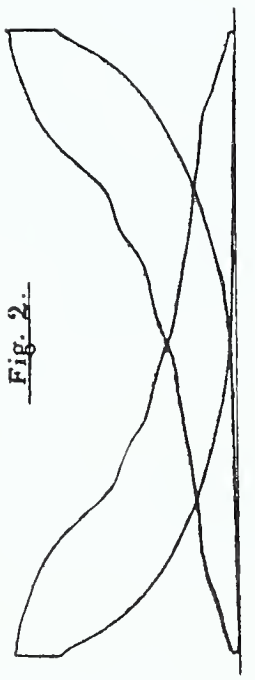


Fig. 2.

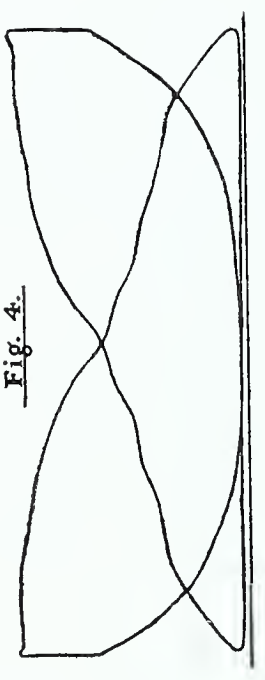


Fig. 4.

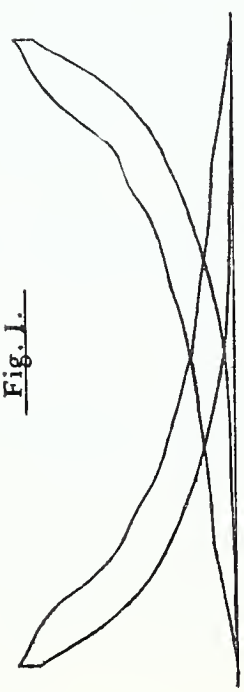


Fig. 1.

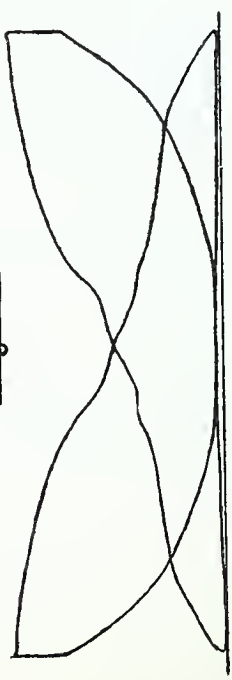


Fig. 3.

Boiler Test.

The test was made on a Stirling boiler. No extended description is needed, as there is a cut of this type of boiler in the advertisements of this annual. It is of the water-tube safety pattern, having 54 tubes 3½-in. in diameter. The principal data of the boiler are given in Table II (page 58).

Two barrels were used in obtaining the weight of the feed water, the one on the scales being above the other so that the water would flow out. City water was used, as no extra pump was at hand to draw water from the cistern. The feed pump had to be run with steam from the boiler that was being tested, as none of the other boilers carried a sufficient pressure. The suction tube of the feed pump was kept in the second barrel so that the pump could be run at a constant speed.

The coal was weighed on platform scales in wheelbarrow loads. Before starting the test the fire and ash-pit were cleaned, and at the end of the test the fire and steam gauge were brought as nearly as possible to the same conditions as at the beginning of the test. The ash in the pit was taken as refuse. No allowance was made for small particles of coal, because the grate bars were close. As the experimenters were not used to firing this style of boiler, the efficiency and capacity are probably less than an experienced fireman might have obtained.

In calculating the efficiency of the boiler, the heating power of Odin coal was taken at 12,663 B.T.U. per lb. of coal, as found by F. H. Clark, '90—see Technograph, No. 5, pp. 22-23. Peabody's tables on saturated steam were used in the computations. The results of the test are shown in Table II (page 58).

Table II—Boiler Test.

Duration of test	5 hours
Temperature of feed water	208°
Average pressure of steam	96.5 lbs
Weight of coal charged	1,602 lbs.
Weight of water evaporated	9,336 lbs.
Weight of refuse	402 lbs.
Refuse	25.1%
Weight of combustible	1,200 lbs.
Evaporation per lb of coal	5.82 lbs.
Evaporation per lb. of combustible	7.78 lbs.
Evaporation per lb. of coal from and at 212°	6.07 lbs.
Evaporation per lb. of combustible from and at 212°	8.12 lbs.
Grate surface	13.25 feet
Coal burnt per ft. per hour	24.2 lbs.
Ratio of grate surface to heating surface	1 to 41.5
Heating surface	550 feet
Water evaporated per ft. per hour	3 39 lbs.
Efficiency of boiler	72 9%
Rated capacity	50 H. P.
Horse-power developed, by Centennial Standard	56.4 H. P.
Per cent. above rating	12 8
Kind of fuel	Odin lump coal, hand fired.

Calorimeter Test.

In order to allow for the water carried away by the steam, we used the Barrus Universal Superheating Calorimeter. The later form of this calorimeter, as described in the Transactions of the American Society of Mechanical Engineers for 1890, was used. This consists of a chamber where a part of the moisture is deposited, and the remainder is evaporated by wire-drawing the steam through an orifice about one-eighth of an inch in diameter. At the lower part of the separating chamber is a drip cock and glass gauge. The steam was permitted to blow through the calorimeter continuously to keep it at a constant temperature. The water was brought to a mark in the glass guage at the start of a test, and after a certain time the accumulation was drawn off. The temperature of the steam before and after throttling was read from two thermometers placed in brass cups filled with oil and surrounded by the steam. On account of the absence of apparatus, the steam blown through the orifice could not be measured, and was therefore calculated by the formula, $Q = 51.4 \times$ Pressure above zero $\times$ Area. This formula is taken from Barrus, the 51.4 being a constant found by experiment. Q gives the quantity in pounds per hour. The per cent. of priming was calculated separately for the water drawn from the separator and that shown in the superheating part.

The formula for priming shown by water in box is: Per cent. priming$=\frac{\text{Water in box}}{\text{Weight of steam}}$. The formula for priming shown by the degree of super-heating is: Per cent. priming$=\frac{h+c\,(t'-t'')-q}{r}$, in which h=total heat, c=specific heat of steam, t′=temperature of steam as shown by lower thermometer, t″=temperature of saturated steam at atmospheric pressure, and r=latent heat of steam at absolute pressure in boiler. The sum of these per cents. gives the per cent. of priming in the boiler. This per cent. was subtracted from the total water pumped into the boiler to find the water actually evaporated.

Referring to Table III the per cent. of priming is seen to be low. It would have been possible to dispense with the separator part of the calorimeter and use only the super-heating part. The limit of use of the super-heating part is about 3 per cent. priming, and our test shows a less amount than this.

From the tests made at different pressures it was found that the boiler gave much dryer steam when the pressure was high. If the pressure indicated by the gauge fell below 80 lbs., the boiler was apt to foam when more than 30 indicated horse-power was developed by the engine.

TABLE III—CALORIMETER TEST.

TIME.		TEMPERATURE.		WATER DRAWN FROM DRIP BOX.	RATE PER HOUR WATER DRAWN FROM DRIP BOX.	BOILER	PER CENT.
START.	STOP.	UPPER.	LOWER.	GRAMS.	KILOGRAMS.	PRESSURE.	MOISTURE.
8.45	9.00	149°C	130°C	51.8	.207	89	
9.45	10.00	160°	134°	56.7	.227	100	
10.15	10.30	161°	135°	50.6	.202	105	
11.15	11.30	148°	128°	55.3	.221	80	
11.45	12.00	159°	135°	59.8	.239	109	
12.45	1.00	159	134°	57.2	.229	105	
AVERAGE		156°C	132.6°C	55.3	221	98	1.77%
		313°F	270.7°F	1.95 oz.	.487 lbs.	98	1.77%

MANUFACTURE OF PAVING BRICK.

By F. M. Spalding, '93, School of Civil Engineering.

A paving brick must be of such density as to be practically impervious to water, and consequently not subject to the action of frost. It should also possess toughness and tenacity to such a degree that the edges will not break off and that the surface of the brick will not wear rapidly when exposed to heavy traffic. A tough, thoroughly vitrified brick possesses these qualifications, as it combines imperviousness to water with great strength and durability.

The shale clay used in making terra cotta pipe generally will make good vitrified brick. A strictly pure clay, that is, one which does not contain any alkalies, is not desirable, as it should not only be able to stand a very high temperature, but should also contain some fluxing agent which will vitrify the brick. The presence of any considerable quantity of lime is particularly to be avoided, as it will cause the brick to disintegrate and scale. At Galesburg the clay is taken from a bluff, and although it resembles sandstone somewhat, it is almost entirely free from grit. Along the Ohio river, shale and coal are taken from the same mine. At present fire-clay is extensively used in the manufacture of paving brick, yet the best results are obtained when it is first mixed with some other kind of clay, since it is almost impossible to vitrify fire-clay. One prominent engineer gives the following as the average composition of paving clay: 69.1 per cent. silica, 15.5 per cent. alumina, 5 per cent. chemically combined water, 2 per cent. moisture, 2.5 per cent. iron, 2.5 per cent. magnesia, and 3 per cent. of lime.

The practice of weathering clay has been extensively followed and has proved to be very beneficial, yet in most larger factories tempering machines are now used instead. During the process of weathering, the clay separates into fine particles so that the contact is very intimate when it is finally made into a brick, hence the brick will be dense and contain very little moisture. The clay must be well mixed and tempered before it is sent to the brick machine. There are three methods of accomplishing this, the soft mud, the stiff mud, and the dry pressed. The average clay can be worked most advantageously as a stiff mud, hence this process is extensively used. In one form of this process the clay is placed in a large iron dry pan as soon as excavated, and then crushed by means of heavy

revolving rollers, into powder, when it drops through the perforated bottom of the pan on a carrier which takes it to the tempering machine. Here it is moistened just enough to make a stiff mud. In another form of the stiff mud process the clay is taken directly from the bank and dumped into a pit, where it is thoroughly worked over by men with spades, then while still in the moistened state it is passed through a crusher and carried directly to the machine. In the soft mud process the clay is placed in a large circular vat where it is mixed into a soft, pasty mass by a rotating wheel having two motions, one along, and one around, its axis. In either method the clay is now ready for the machine. The dry pressed process is very rarely used for paving brick.

The brick machine should compress the clay the utmost possible amount. The softer the clay leaves the machine the greater will be the shrinkage from drying and burning, and also the greater will be the loss in handling. With the stiff clay process the clay is forced out of the machine in a continuous bar, which is cut off as it leaves the machine, by means of wires strung in a frame which works either automatically or by hand. The brick may be either side or end cut. In the soft mud process the clay is forced into molds, which are removed as fast as filled.

The next step is to dry the brick. While some of the old-time brickmakers still persist in using the sun as their only means of drying, the majority of intelligent brickmakers use some form of artificial dryer. In one form, which is frequently used, there are coils of steam pipe under a slatted floor. The brick are loosely tiered up on this floor, and are dried by the radiation of the heat from the steam pipes. In another form the floor itself is heated by means of brick or tile flues, the brick being dried by direct contact with the heated surface. In the tunnel dryer the brick are placed on iron cars and run into the tunnel, and heat and smoke allowed to pass directly through the tunnel. The brick are completely dried in the tunnel dryer in twenty-four to thirty-six hours. Sun dried brick are usually only partially dried when placed in the kiln, which necessitates a great deal of water smoking. A prominent brickmaker says: "It costs from $1.00 to $2.00 per thousand to dry brick in the kiln, and the result is second or third class brick; while the brick can be thoroughly dried before being set in the kiln for 25 to 50 cents per thousand, and the result is first-class brick."

The last and most important step is the burning. There ar e

two classes of kilns, the up and the down draft. The up draft kiln is simply a great rectangular pile of brick tiered loosely, with the exception of the outside courses, which are laid solid with mortar. The top is left open to permit the heat and smoke to pass off. The fires are built under the kiln on all sides, and the heat and smoke passes up through the brick and out at the top. This kiln can be used but once, and a new one must be built for the next lot of brick. It is not so generally used for burning pavers as the down draft. The most popular form of the down draft is the Eudaly. This is a permanent brick structure having 24-inch walls and a thick brick arch top. It may be built either round or square, and the capacity varies from twenty-five to two hundred and fifty thousand. There are furnaces all around the outside of the kiln, and within the walls of the kiln at frequent intervals are small chimneys extending from the flues below the floor to a few feet above the crown. The heat and smoke from the furnaces pass through the walls of the kiln into fire boxes which conduct the heat to the top of the kiln before coming in contact with the brick. The heat then passes down through the brick and out of the perforated bottom into a system of flues which connect with the small chimneys. Each chimney is provided with a damper so that the heat may be shut off from any part of the kiln, thus placing the kiln under perfect control. It usually takes sixty hours to water smoke, and from four to six days more to finish the burning. The amount of coal consumed per thousand brick varies from 600 pounds to 2,000 pounds, according to the character of the clay and the quality of coal. A number of brick makers are using oil or gas fuel in firing their kilns, claiming that it makes a cheaper fuel and one which is more easily regulated. The time required in burning pavers is slightly more than for burning common brick, owing to the increased length of time which the heat must be held for vitrification.

The process of vitrifaction is as follows: "Clay is a silicate of alumina with foreign admixtures of sand, iron, lime, magnesia, and alkalies. Under the action of heat the alkalies melt and at the same time, the lime, iron, and magnesia begin to act as fluxes. Continue to increase the heat and the solvent action increases. When all the particles have become impregnated with the melted portion we have reached vitrifaction." A uniform temperature must be maintained and if the burner finds one part of the kiln is vitrifying faster than another, he must retard the heat in that portion. The

temperature required for vitrifaction is 2,000° to 2,500° F. The kiln must be allowed to cool very slowly, as it is the slow cooling which tempers the brick and gives it the required toughness. From 75 to 90 per cent. of the brick placed in the kiln are fit for pavers, and nearly the entire remainder can be used for building brick.

The following table taken from "Durability of Brick Pavements" by Prof. I. O. Baker, gives the results of some tests made at the University of Illinois on bricks which have been extensively used in pavements, and which have shown great durability.

REF. NO.	LOCALITY.	QUALITY.	TRANSVERSE STRENGTH, MODULUS OF RUPTURE IN POUNDS PER SQUARE INCH.	ABSORPTION POWER IN PER CENTS OF THE WEIGHT OF THE DRY BRICK.	SPECIFIC GRAVITY.	CRUSHING STRENGTH OF CUBES IN POUNDS PER SQUARE INCH.	LOSS BY ABRASION DURING THE THIRD HALF HOUR IN PER CENTS OF ORIGINAL WEIGHTS.
1	A_1	Top course.....	1,712	4.5	2.10	13,085	0.8
2	A_2	Bottom course	1,013	8.5	1.90	6,860	2.6
3	B_1	Top course.....	1,496	1.3	2.21	10,545	0.7
4	B_2	Bottom course	1,243	5.9	2.08	9,925	2.0
5	B_3	Old product.....	1,686	4.8	2.11	9,820	2.5
6	C	....	1,680	1.2	2.21	5,260	0.4
7	D	.....	1,247	7.1	1.98	5,691	3.0
8	E	.....	1,336	2.6	2.12	5,468	1.3
9	F	.....	1,790	6.1	2.15	9,494	1.9
10	G_1	Old product.....	1,187	12.5	1.74	5,185	3.7
11	G_2	New product...	1,429	4.8	1.87	6,190	.....
12	H_1	New product...	2,120	3.5	2.24	8,230	1.2
13	H_2	Old product.....	.....	2.5	2.26	5,890	1.2
14	I	.....	1,000	2.0	.....	3,460	0.5

PRIMARY BATTERY TESTS.

By W. G. Miller, '92, and W. H. Foster, '92, School of Mechanical Engineering.

A primary battery may be defined as a cell in which the materials that compose it are in such a state of combination as to generate an electric current. There are two classes of these batteries, distinguished from each other mainly by the nature and action of the depolarizer used,—the "Open" and "Closed" circuit batteries. Open circuit batteries are those that are adapted to stand on open circuit, and to generate a current at intervals of a few seconds only, without loss or waste. Those are termed closed circuit batteries which work on a closed circuit for a considerable time, through a small resistance, with very little change in the strength of the current. The dry battery is a form of the open circuit type in which the excitant is in the form of a porous, pasty mass.

Our tests were made on three open circuit batteries, two of which—the "Gonda" and the Gonda "Porous Cup"—were of the liquid type, and the third—the Mesco—the dry type, and also on the Taylor battery of the closed circuit type.

A complete test of a battery consists in determining its electromotive force, difference of potential at its terminals, internal resistance, and output in amperes when its circuit is first closed, the rate at which these quantities change because of the polarization when its circuit is kept closed for a considerable time, and the rate at which it recovers from its polarization when the circuit is left open. Although the open and closed circuit batteries differ so materially, a test of each is conducted by the same method, the test of the closed circuit battery merely taking a longer time.

The method used in these tests is known as the condenser method. This consists of charging a condenser with the battery under consideration, and then by means of a discharge key, discharging this charge through a high resistance galvanometer. Since the capacity of the condenser remains constant, the deflections of the galvanometer will be proportional to the electromotive forces; and by comparing these deflections with the deflection given by the known electromotive force of a standard cell, the electromotive forces

become known. A Cahart-Clark standard cell, having an electromotive force of 1.441 volts, was used for this purpose.

The potential difference is determined in the same manner, the condenser being charged and discharged through a known resistance while the circuit is closed. Since the current is equal to $\frac{E}{R}$, it becomes known upon the E being determined. Also the internal resistance becomes known, being equal to $R\frac{E-E'}{E'}$. In both of the relations R is the external resistance, E the electromotive force, and E' the potential difference at the terminals.

To determime the rate of change caused by polarization, the circuit is kept closed through the known resistance and the potential difference read at definite intervals. The electromotive force is also taken at intervals by breaking the circuit long enough to charge and discharge the condenser. The rate of recovery is obtained by noting the electromotive force at intervals after the circuit is open. A one third microfarad standard condenser and a Thompson's square-pattern, high resistance galvanometer were used in carrying on these tests. The data observed in making the tests may be expressed graphically in curves, the time being used as abscissas and the volts, amperes, ohms, and watts as ordinates. By means of these curves one can see at a glance the exact electromotive force, potential difference, internal resistance, and current of the battery under consideration at any time during the test.

Referring to the upper diagram of Plate I, page 68, we observe that for the Gonda "Porous Cup," the electromotive force commences at 1.63 volts, and during the first ten minutes drops 0.35 volts, and then the polarization is gradual to the end of the test, when the electromotive force is 1.195 volts. The recovery shows a rapid rise during the first six minutes after the opening of the circuit, when it increases more slowly in value, and after three quarters of an hour was still 0.14 volts less than the initial electromotive force. The recovery curve is plotted back from the end of the polarization curve toward the left, so as to show better the action of the voltage at the end of the hour and a half test.

The terminal potential difference decreases in electromotive force about the same rate as the polarization from 1.29 volts down to 0.97 volts. The shortening of the vertical intercepts between the two curves shows the decrease in the internal resistance during the test. The current is quite regular and averages 0.2 of an ampere.

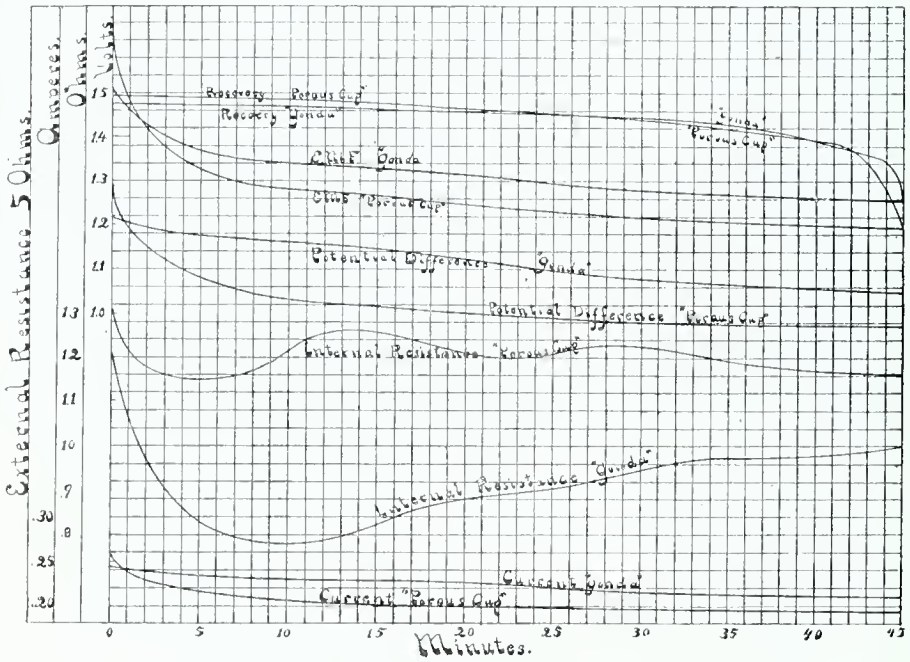
Upon the same diagram are shown the curves of the "Gonda" battery. Here the polarization is more continuous and does not decrease so suddenly. The potential difference is also nearly continuous from the start, while the internal resistance is smaller than in the "Porous Cup." The recovery shows a gradual increase until the end of the test, when it is but 0.04 volts less than the initial electromotive force. The current is very regular, the total fall being but 0.03 amperes, showing a very steady current for an open circuit battery.

The Meseo Dry Battery, the curves of which are shown in the bottom diagram of Plate I, represents a good type of that class of batteries. The polarization decreases slowly from 1.5 volts to 1.37 volts, and recovers leisurely to 1.45 volts. The potential difference decreases leisurely from 1.41 volts to 1.265 volts. The increase at the start in the length of the vertical intercepts shows an increase in internal resistance. The current gradually decreases and the fall during the test is 0.03 amperes, making an average current of 0.26 amperes. Any person comparing the curves of this battery and those of the Gonda cannot help but admit that this battery makes a favorable showing with the type of the zinc carbon battery set up with a liquid exeitant.

The Taylor battery, the curves of which are shown in Plate II, was a new battery, carefully set up, and is of the closed type of batteries. It was given a most severe test, being in circuit twenty-eight hours. As shown by the curves, it started with the wonderfully high electromotive force of 1.86 volts and the current of 1.38 amperes. After fifteen minutes these had fallen only to 1.8 volts and 1.2 amperes, while for the next twelve hours they remained practically constant. This shows how well this battery is adapted for running motors, etc., where a high electromotive force and a large current are required to be constant for a considerable length of time. The energy obtainable for power is represented by the curve marked "external energy" and shows the comparative constancy of output for the first half of the test. The internal energy is large throughout, showing a mean of about 0.6 watts, while the maximum external energy is but 2.05 watts. This large loss of energy internally, as compared with the external energy, is due to the high internal resistence, being at least 0.5 of an ohm for all but the first fifteen minutes, while the external resistance is but little over 1.0

ohm. This shows that the battery would be more efficient when used with higher external resistance. The recovery is very rapid, the battery recovering upon the opening of the circuit 0.4 of a volt in a few minutes, while it finally reaches its voltage at constancy of 1.8.

The makers recommend that the solutions of the battery be no longer used after they show a certain loss in density, but this was disregarded to notice what the results would be. What the results were, are represented by the curves and show a rapid decrease in all but the internal resistance, which, rising quite rapidly near the end, shows that the battery was working at a great disadvantage because of some local action. This culminated in the peculiar jump represented by all the curves, the internal resistance being particularly effected.


External Resistance 5 Ohms.
Amperes.
Ohms.
Volts.
Recovery "Porous Cup"
Recovery "Gouda"
"Gouda" "Porous Cup"
Ohms "Gouda"
Ohms "Porous Cup"
Potential Difference "Gouda"
Potential Difference "Porous Cup"
External Resistance "Porous Cup"
Internal Resistance "Gouda"
Current "Gouda"
Current "Porous Cup"
Minutes.

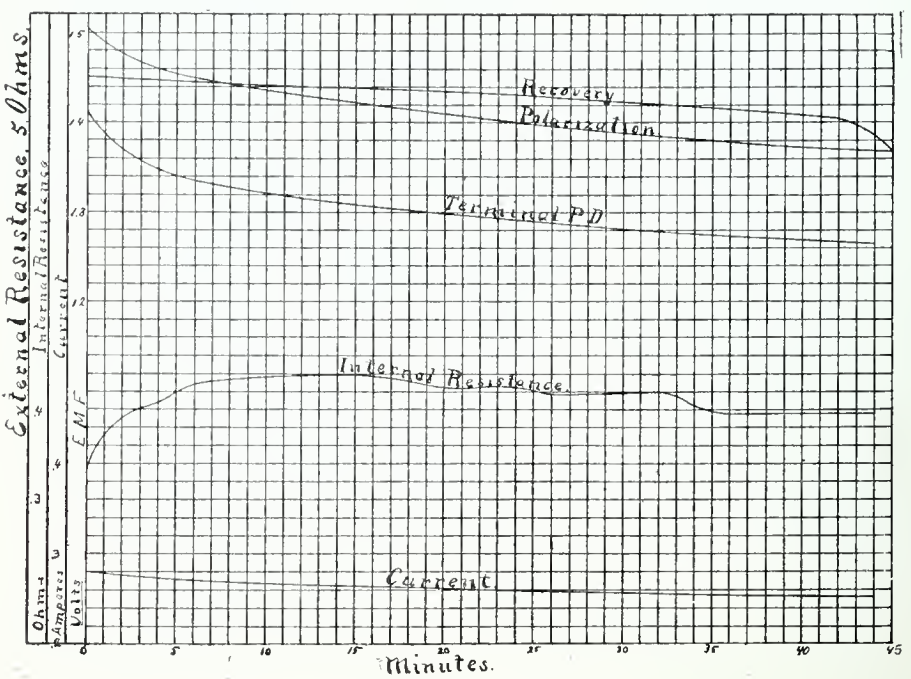

External Resistance, 5 Ohms.
Ohms
Internal Resistance
Amperes
Current
Volts
EMF
Recovery Polarization
Terminal PD
Internal Resistance
Current
Minutes.

PLATE I.

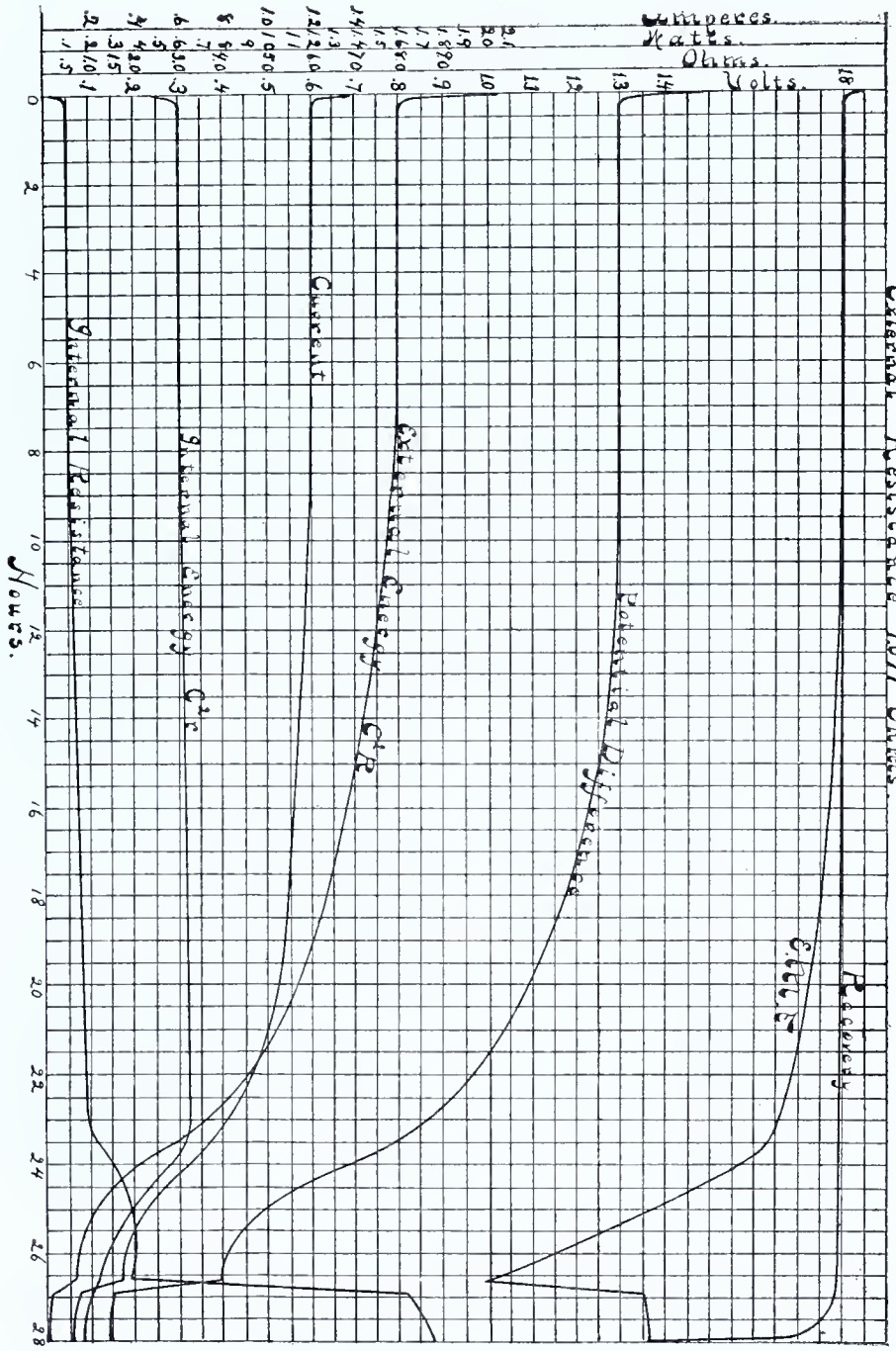

Amperes.
Watts.
Ohms.
Volts.
Hours.
External Resistance 1.071 Ohms.
Current
External Electromotive Force
Potential Difference
Internal Resistance
Internal Electromotive Force
Efficiency

PLATE II.

DIAGRAM FOR FLOW IN PIPE SEWERS ACCORDING TO KUTTER'S FORMULA.*

By Arthur N. Talbot, Professor of Municipal Engineering.

Kutter's formula for the flow of water in pipes, conduits, channels and streams has obtained wide acceptance among engineers on account of its great flexibility and adaptability to varying conditions of slope, depth and roughness of channel. Its objectionable feature is that its complex nature requires tedious computations in its application. Within the range of the gradients of sewers, the formula may be simplified and yet remain within the necessary limits of accuracy: and the diagrams herewith presented render the use of this reliable formula simple and rapid for obtaining velocity and discharge of ordinary vitrified pipe sewers.

Kutter's formula in feet measure is

$$V = C\sqrt{RS} = \frac{41.66 + \frac{1.811}{n} + \frac{0.00281}{S}}{1 + (41.66 + \frac{0.00281}{S})\frac{n}{\sqrt{R}}}\sqrt{RS}$$

in which

R=hydraulic mean radius, found by dividing the area of cross section by the wetted perimeter.

S=gradient, or sine of inclination, or fall in feet per foot.

V=velocity in feet per second.

n=coefficient of roughness, depending upon surface of pipe.

C=coefficient represented by fraction.

The value of the coefficient of roughness, n, is generally considered by engineers as .013 for pipe sewers under usual conditions. For clean, smooth pipe, it may easily be , and some observations have given as low as .010. For pipe sewers laid under usual conditions, even when they are not thoroughly flushed, .013 may be used with safe results, and this value has been chosen for calculating the diagrams. For selected pipe, well laid and thoroughly flushed, .012 will probably give correct results.

*Since this article has been put in type, the writer has accidentally found that a diagram involving the same principles was published by Rudolph Hering, C. E., in Trans. Am. Soc. C. E. for 1879. It is believed that its publication here will be of value to many who would have no opportunity to use the other diagram. The writer desires to express his obligation to A. B. Loomis, '93, and R. C. Vial, '93, for valuable assistance in the computations and in the preparation of drawings.

Calculations on the effect of substituting .012 for .013 show that the increase in the velocity, and therefore in the discharge, ranges from 10 1 per cent. for 24-in. pipe to 11.3 per cent. for 6-in. pipe, with an average of 10.7 per cent. for all the sizes of pipe used in the diagram. However, it will be sufficiently accurate to add 10 per cent. to the values obtained with $n=.013$ in order to find the values with $n=.012$. In a similar manner it may be shown that $n=.015$ gives results 17 to 18 per cent. less than $n=.013$.

While changes in S at the light grades of rivers, canals, and very large sewers affect the value of C considerably, the widest variations in the grades with which pipe sewers are used has a comparatively small effect. If C be calculated with $S=.001$, and this value of C be used for computing V for other gradients, the result will exceed the true value of the original formula for grades steeper than .001 and fall short for lighter grades. For 24-in. pipe this error will be 1 3 per cent. when $S=.0005$, and also when $S=.04$. For 12-in. pipe the error reaches 1 8 per cent. at the same gradients. As these inclinations represent the extremes of practice, and as the error decreases rapidly toward $S=.001$, this form is well within the limits of accuracy required in sewerage practice, especially as there are considerable variations in the size and roughness of pipe and great uncertainty in other data for sewer requirements.

Using $S=.001$ and calling $n=.012$, .013 and 015, respectively, the coefficient C in Kutter's formula becomes

$$\frac{195.39}{1+\frac{.534}{\sqrt{R}}},\quad \frac{183.78}{1+\frac{.578}{\sqrt{R}}},\quad \text{and}\quad \frac{165.2}{1+\frac{.667}{\sqrt{R}}}.$$

When R for particular sizes of pipe is substituted in the formula, it reduces to the form $V=m\sqrt{S}$, where m represents the resulting constant. Substituting x for $\sqrt{S}$, the formula becomes $V=mx$, the equation of a straight line passing through the origin. This property may be utilized by platting the square roots of the gradients as abscissas and the velocity as ordinates, when the flow of any pipe will be represented by a straight line. The diagrams are constructed on this principle. The abscissas are laid off as the square root of the gradient and the ordinates directly as the velocity, and each size of pipe is represented by a straight line. The origin does not come within the limits of the diagram. The axes of abscissas and ordinates are placed at an oblique angle in order to obtain better inter-

sections and to increase the range of the diagram. The equation of discharge of pipes will likewise be shown by straight lines, since it is the product of the velocity by a constant area of cross section.

Great care was taken in the construction of the diagrams. Every computation was made by two computers, usually with the aid of the Thomas computing machine, the Thacher slide rule, or logarithms, and four points were obtained for every velocity and discharge line; so the check on both calculation and drawing makes it reasonably certain that there are no errors of any consequence.

Explanation of Diagram of Velocities.—The abscissas represent gradients and the ordinates velocities; hence all points on a vertical line have the same gradient, and all points on a nearly horizontal line represent the same velocity. The gradient is the sine of the inclination or the fall in feet per foot. To find the velocity at a given gradient, follow the vertical line representing the gradient to its intersection with the diagonal line of the desired pipe. The velocity line followed to the side of the diagram will give the resulting velocity. Intermediate values may be interpolated by the eye. The velocity is for pipes running full or half full. For values at other depths, see table given elsewhere. For $n=.012$, add 10 per cent. to the results of the diagram.

Explanation of Diagram of Discharge.—The abscissas represent gradients and the ordinates discharge in cubic feet per second; the vertical lines represent all points having the same gradient and the horizontal those having the same discharge. A scale giving discharge in millions of gallons per day is added at the left margin. To find the discharge of a pipe running full, follow the vertical line representing the gradient to its intersection with the line of the desired pipe. Then follow the discharge line to either side of the diagram. Intermediate values may interpolated by the eye. For pipes running less than half full, see table given elsewhere. For $n=.012$, add 10 per cent. to the results of the diagram. To determine necessary size of pipe, enter the diagram on the line of the desired discharge and find its intersection with the line of the pipe, and read the gradient line. To determine size necessary to carry a given discharge, find intersection of discharge line and gradient line. The next pipe above will give the necessary size. Since the discharge of 6-in. and 8-in. pipes would not be within the limits of the diagram, 10 times their actual discharge was platted. For 6-in. and 8-in. pipes, then, the results of the diagram must be divided by 10. The dotted

DIAGRAM OF

VELOCITIES

ACCORDING TO KUTTER'S FORMULA

with **n = .013.**

Pipes full or half full.

For velocity with $n = .012$, add 10 per cent to these results

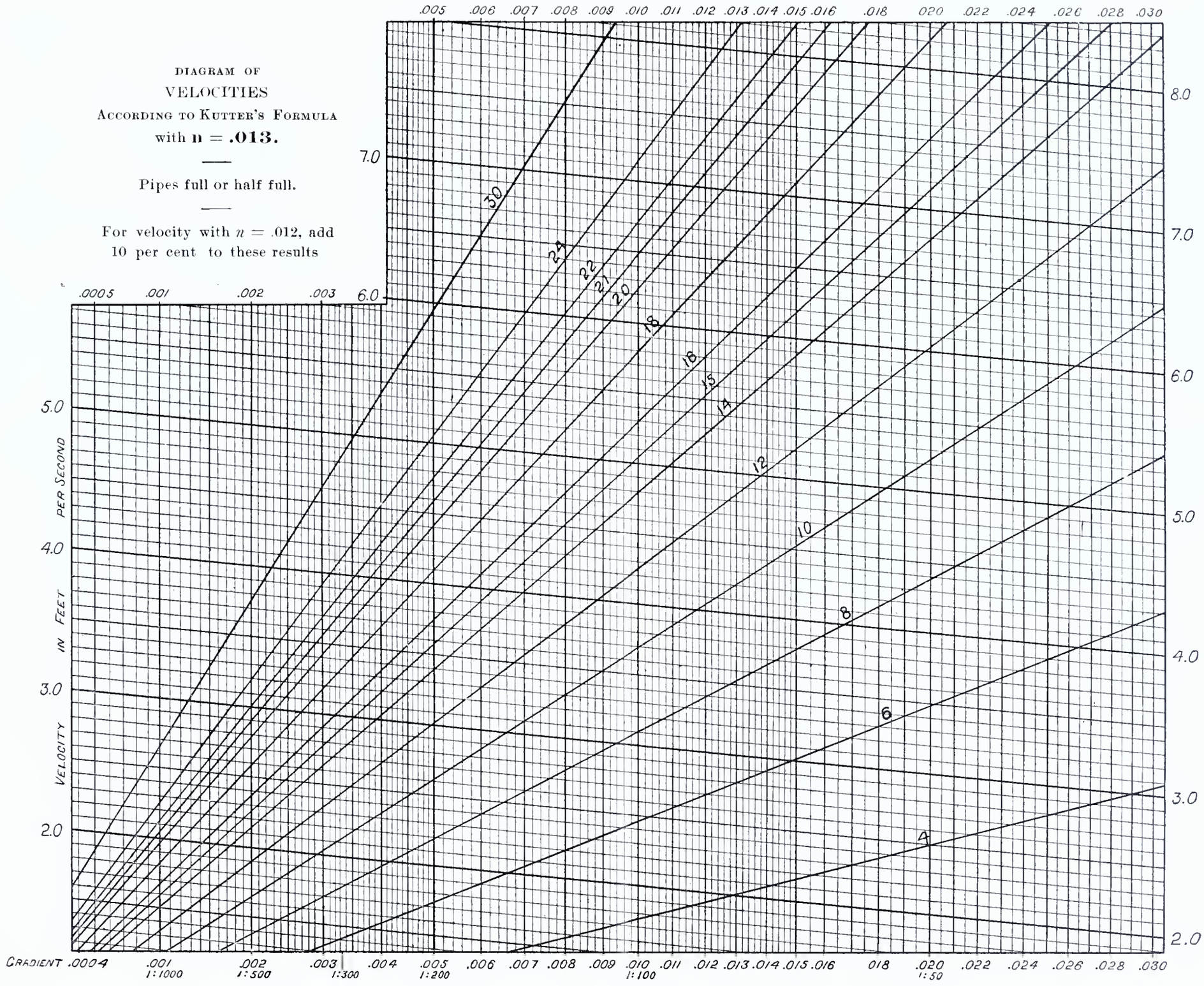


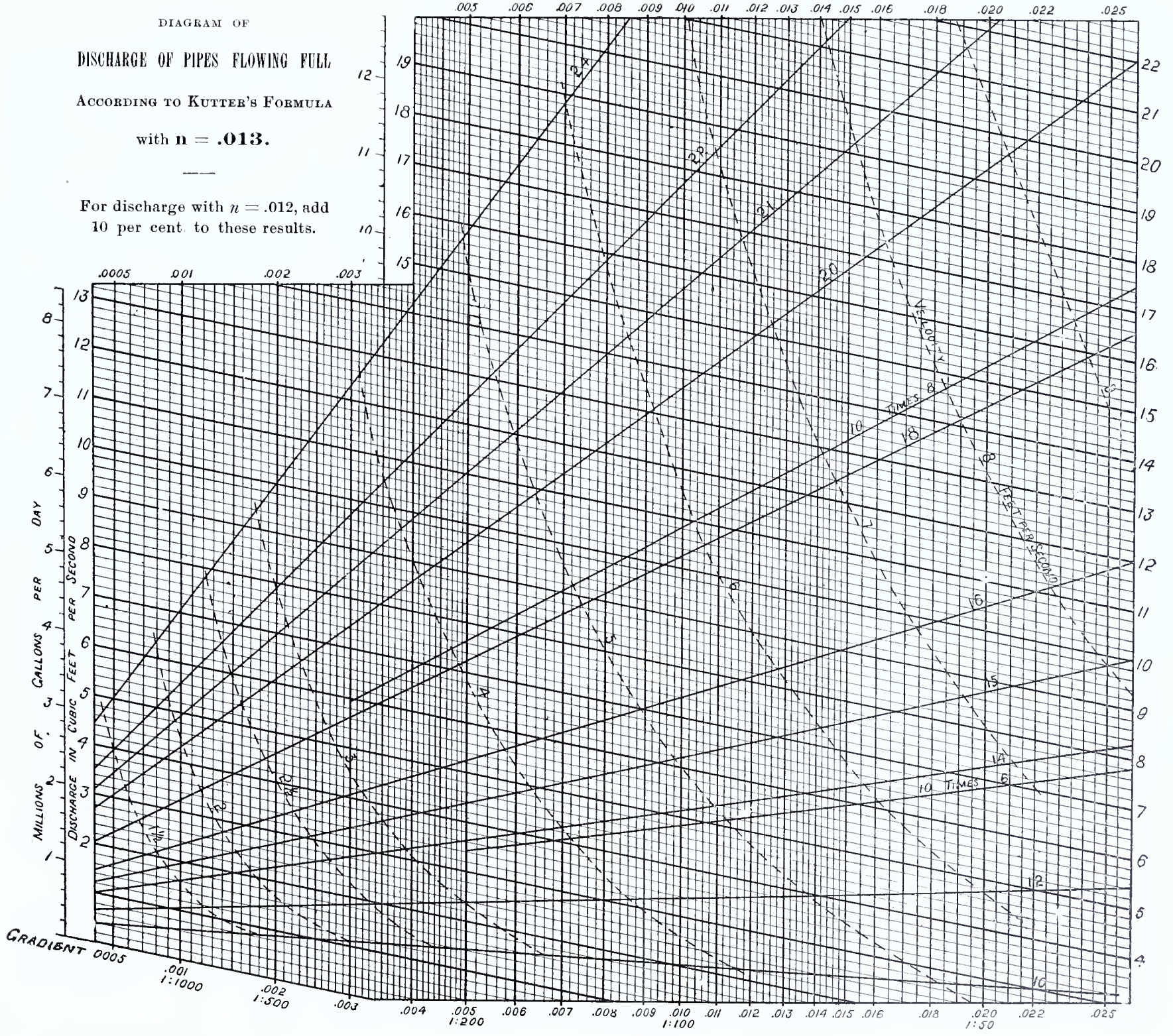
DIAGRAM OF

DISCHARGE OF PIPES FLOWING FULL

ACCORDING TO KUTTER'S FORMULA

with **n = .013.**

For discharge with $n = .012$, add 10 per cent. to these results.



lines show the velocity in the pipes at the gradients crossed. Intermediate velocities may be correctly obtained by interpolating proportionally, since each line of pipe is divided uniformly by the velocities.

Velocity and Discharge of Pipes Partially Full.—The flow of pipes partially full is frequently of importance, as when the depth and velocity of a sewer at its minimum discharge are desired. While it is common to consider that for the same pipe the velocity varies as the square root of the hydraulic mean radius of the section covered at the given depth, or in other words that C remains constant for different depths, yet Kutter's formula gives different results. The Darcy-Bazin experiments are the only ones known to the writer in which observations at different depths of circular pipes have been made, and these extended only to half full. The results are considerable closer to Kutter's formula than to the assumption that C remains constant. As Kutter's gives a smaller value for depths below the center it is on the safe side. While the formulas indicate a greater flow for depths from eight-tenths full to full than when flowing full, no great reliance should be placed on this excess. It is safe to say that above eight-tenths of the diameter the discharge is at least as great as when flowing full, and that above half the diameter the velocity is more than when flowing full or half full.

The following table gives the velocity and discharge at different depths in terms of the velocity and discharge when flowing full, both on the assumption that C remains constant and that it varies as given by Kutter's formula. The values by Kutter's are averages for the different sizes of pipes, but the variation in any case is comparatively small. The depth is given in terms of the diameter.

TABLE OF VELOCITY AND DISCHARGE OF PIPES PARTIALLY FULL.

All values are given in terms of values for full pipes.

DEPTH.	C CONSTANT.		KUTTER.	
	VELOCITY.	DISCHARGE	VELOCITY.	DISCHARGE.
1.0	1.09	1.00	1 00	1 00
.9	1.09	.99	1 14	1 08
.8	1.10	.94	1.15	.99
.7	1.09	.82	1.12	.84
.6	1.05	.66	1.08	.68
.5	1.00	.50	1.00	.50
.4	.93	35	.89	.33
.3	.83	.21	.75	.19
.2	.70	.10	.57	.08
.1	.50	.02	.34	.02

To find the velocity or discharge at any given depth, divide the depth by the diameter and multiply the velocity or discharge of full pipes as found in the diagrams by the value given in the table opposite the partial depth. To find the depth of flow, divide the given velocity or discharge by the quantity found in the diagram and find in the table the depth which gives a value nearest this quotient.

It was intended to include in this paper diagrams for sewers larger than 24 inches, both circular and egg-shaped, but the time for publication did not permit. It may be added that the approximate formulas on page 71 may be used advantageously in the following form :

$$\frac{195.4\ R\sqrt{S}}{\sqrt{R}+.534},\quad \frac{183.8\ R\sqrt{S}}{\sqrt{R}+.534},\quad \frac{165.2\ R\sqrt{S}}{\sqrt{R}+.667}.$$

NOTE ON THE COMPRESSIVE RESISTANCE OF BRICK.

By Ira O. Baker, Professor of Civil Engineering.

Elsewhere the writer has called attention to the fact that the flatness of the pressed surfaces greatly affects the crushing strength of cubes of brick or stone. The present note is written to present the results of some experiments made to determine the effects of different methods of preparing the pressed surfaces of the test specimens.

In testing some paving brick, the writer made some preliminary experiments by preparing the surfaces in five ways, viz : 1, grinding as nearly flat as possible upon the convex side of an emery stone, and crushing between self-adjusting, parallel, cast-iron plates ; 2, removing the irregularities of the surface by grinding, and crushing between blotting paper ; 3, removing the irregularities of the surface, and crushing between straw board ; 4, removing the irregularities of the surface, coating with plaster of Paris and placing under

slight pressure until set (12 to 24 hours), and then crushing; and 5, coating with plaster of Paris which was afterwards ground down on a sand-paper disk, to the surface of the brick so as to leave a minimum thickness with a perfectly flat surface, and then crushing.

After a considerable number of experiments, it was decided that there was no great difference between the first three methods, while the difficulties in applying the last two were so great as to render them worthless. With a grade of brick which was quite uniform in quality, the first three methods gave 7,000 to 9,000 pounds per square inch as the crushing strength of cubes. The fairly close agreement of the results was considered satisfactory evidence that the method employed secured the full strength of the brick. Subsequently the writer decided to determine the strength of cubes when the pressed surfaces were prepared with the greatest care. The samples were prepared on a rubbing bed at a marble dressing establishment, by the ordinary workmen, with instructions to secure perfectly flat surfaces. The brick were of the same grade as those referred to above, and many of the samples were the second halves of the brick used in the first experiments. The strength of the carefully prepared cubes ranged from 16,000 to 21,000 pounds per square inch, and averaged a trifle over 18,000.

The conclusion derived from the two series of experiments is that an almost imperceptible difference in the flatness of the test specimens makes a very great difference in the strength. Obviously this difference is greater the harder and more brittle the brick or stone. It is perhaps well to repeat that tests of compressive resistance of blocks of stone or brick are useful only in comparing different samples, and give no idea of the strength of masonry constructed of these materials.

It is interesting to notice that Rankine and Trautwine, standard British and American authorities, in editions of their engineers' manuals published a few years ago, give the crushing strength of the best brick at 1,100 and 4,000 pounds per square inch, respectively; while there has recently been tested in the University testing laboratory three lots of brick which averaged from 15,000 to 18,500 pounds per square inch. The difference is probably due mainly to improvements in the manufacture of brick. The crushing strength of granite, when tested under similar conditions, is from 12,000 to 20,000.

OUR CEMENT WALK.

By R A. Mather, '92, School of Civil Engineering

The University grounds were further improved, last fall, by the laying of a cement walk leading from the street-car line to the main building and to the chemical laboratory. The building of this walk gave the engineering students an excellent opportunity to keep a force and material account. This paper is written simply for the interest of the engineering students, to give an example showing how one may learn the approximate cost of labor and material in such works. The data were obtained by daily observations of the work while in progress, and has been checked by inquiry of the party furnishing the gravel and sand and at the freight office, and is reasonably correct. It is perhaps well to say that the writer made these observations as a part of his work in the study of masonry construction, and that he had no official connection with the building of the walk. There was no engineering supervision of the work.

The bid was $1.60 a square yard for three and one fourth inches of concrete of one part of cement to six of gravel, and three fourths of an inch of mortar of one part of cement to one of sand, if the University furnished the foundation ; or $1.80 a square yard if the contractor furnished it. Since there was a cinder walk already laid, which was suitable for a foundation, the University accepted the first bid. The difference between the two bids is too small, for the foundation ought not to be less than six inches of gravel—the cheapest material in this locality. A six inch layer of loose gravel would cost, at the price the contractor did pay for gravel delivered, eighteen cents a square yard, which would leave but two cents a square yard for labor in excavating, laying, tamping, and for shrinkage.

The cinder walk, built about six years ago, serves as a foundation to the cement walk. In constructing this cinder walk eight inches of earth was dug out, and the trench thus formed was partly filled with broken brick. The brick were covered with coarse cinders, which were rolled until packed into a hard mass four inches thick. The coarse cinders were covered with a well-rolled layer of screened cinders, which completed the walk.

The contractor for the cement walk removed the layer of fine cinders, after which he was ready to lay the concrete. Two scant-

lings, two by four inches, were laid lengthwise with the walk and six feet apart. Between these the concrete was laid and rammed. The gravel used was medium coarse and contained some sand. On the concrete the mortar was laid and smoothed over with the trowel. The walk was divided into blocks six feet long, by an iron blade about a quarter of an inch thick, which was pounded down as it was drawn across the walk. The walk was left to harden, exposed to the open air. In four or five days it was ready for use.

Since the opening of spring long cracks have opened in the walk, which are probably due to the settling of part of the foundation. As the cinder walk was not quite wide enough, it was necessary to dig away the earth and fill in on each side. It will readily be seen that if this addition to the foundation was left in such a condition that it would settle after the walk was completed, the top covering of concrete and mortar would settle along the sides and produce a bending moment at the center, which, if great enough, would cause the walk to crack.

TABLE I.—DIMENSIONS OF THE WALK.

121	feet of	4½-feet	walk	550	square feet.
480	" "	6 "	"	2,280	" "
17	" "	3 "	"	50	" "
160	" "	1-foot "		160	" "
		Total area		3,640	square feet.

TABLE II.—COST OF MATERIAL AND LABOR.

60	barrels of German Portland cement, @ $3.00, at Chicago	$180.00
5	" " " " " @ 4.25, at Champaign	21.25
	Freight on cement	25.00
40	cubic yards of gravel, @ $1.00, delivered	40.00
11	" " " sand, @ $1.00, "	11.00
4	men, 6½ days, @ $2.00	52.00
2	" " " @ $4.00	52.00
	Total	$381.25

Let us try to determine whether the material furnished is sufficient to fulfill the contract. The area of the concrete is 3,640 square feet, its thickness is $3\frac{1}{4}$ inches, and the cubic contents is 36.5 cubic yards, which will require approximately an equal amount of gravel. According to Table II., we see that 40 yards were used, which satisfies the specifications reasonably well, if allowance be made for waste and for shrinkage in ramming.

The area of the wearing coat is 3,640 square feet, its thickness

is three fourths of an inch, and the cubic contents are 8.43 cubic yards. This was to be a one to one mortar, and according to Prof. Baker's "Treatise on Masonry Construction," page 86, one cubic yard of one to one mortar requires 0.58 cubic yards of sand and 4.16 barrels of cement, and therefore 8.43 cubic yards of mortar would require 4.89 cubic yards of sand and 34 barrels of cement. According to Table II, 11 cubic yards of sand were used, or, allowing for waste, the amount was twice that called for by the specifications.

The concrete was to be one part of cement to six parts of gravel. Therefore the 36.5 cubic yards of concrete, as stated above, would require a little more than 6 cubic yards of cement. From Prof. Baker's "Treatise on Masonry Construction," page 86, we see that 7.14 barrels of Portland cement make one cubic yard; hence 6 cubic yards will be 42 barrels. The wearing coat required 34 barrels as shown above. Therefore there should have been used 42+34=76 barrels of cement. If the proper quantity of cement, 42 barrels, was used in the concrete, only 23 barrels were left for the top coating. The cement in the wearing surface was only two thirds, and the sand was twice that required for the one to one mortar as specified; or, in other words, the wearing surface is a one to three instead of a one to one mortar. The walk is wearing rough, which shows a lack of cement.

TABLE III.—PROFIT AND LOSS ACCOUNT.

404.4 square yards @ $1.60		$647.10
Material and labor as in table II	$381.25	
Lumber for mortar boxes, drayage, supervision, etc., (estimated)	70.85	452.10
Net profit, 30 per cent. on $650		$195.00

RELATIVE EFFICIENCY OF DIFFERENT CUTTING ANGLES IN LATHE TOOLS.

BY E. S. KEENE, '90, SCHOOL OF MECHANICAL ENGINEERING.

The following experiments were made to determine the relative amount of power required to operate lathe tools having different cutting angles. The apparatus used was a spring dynamometer attached to the face-plate of a lathe, as shown in Fig. 1. *A*, *A* are two blocks screwed into the face-plate. One end of the spring was fastened to

the left hand block, the other to the axis of the spring. The axis of the spring passed freely through holes in the blocks A, A, so as to receive the thrust of the dog driving the piece operated upon. The strip of paper upon which the diagram was to be traced, was carried by a series of rollers, R, R, R. The feed was produced by means of a screw and wheel motion, B, C, run by a belt and pulleys, D and P, back of the face-plate In tracing the diagram two pencils were used, one of which was attached to the frame of the register and traced a straight line. The other was attached to the axis of the spring in such a manner as to move with it and register the compression of the dynamometer spring. Before taking an experiment the pencil points were adjusted by means of suitable screws, T, T, so as to trace the same straight line. Therefore the distance between the two lines traced is proportional to the force required to drive the piece.

The spring was tested by compressing it between a fixed beam and the platform of a pair of scales and measuring the shortening corresponding to known compressions. From the average results thus obtained it was found that a compression of one inch required 189.6 pounds. The length of arm pressing against the axis of the spring changed with the different degrees of compression. The length of arm was six inches when the spring was compressed three tenths of an inch, which was about the average compression. Any considerable variation of the compression from that amount was noted and the corresponding change of length of arm allowed for in computing the force at the center of the cut.

For measuring the angles of rake of the different surfaces, a bevel protractor was used and the angles taken which the different surfaces made with planes, horizontal and vertical to the axis of the tool. By rake is meant the inclination or angle, above a horizontal line or in the direction of the arrow, Fig. 2. The angle made by the forward inclination of the tool will be called the *clearance*. That to the side, the *side rake*, and the angle made by the surface B, Fig. 2, with the horizontal plane, the *top rake*.

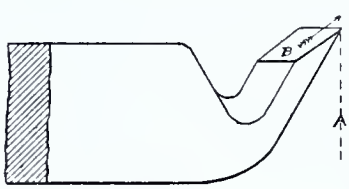


Fig. 2.

The strength of the cutting edge is determined by the angles of rake and of clearance. The keenness of the tool, though dependent to some degree upon the amount of clearance and side rake, is

much more dependent upon the angle of the top face. In a tool having twenty or twenty-five degrees of top rake, the chip will come off almost straight and the thickness very nearly the amount of the forward feed; but with no top rake, the chip will be very much thicker than in the first case, and will be ragged and broken up. This thickening and bending requires an expenditure of driving power diminishing the depth of cut the lathe is capable of driving. The diameter of the curl of the chip, depends upon the amount of top rake, the greater the rake the greater the coils of the chip, and therefore the less the amount of power expended in bending and thickening the chip. But if the cutting edge is thin it dulls sooner than when it is thick, so that what is gained in large angles of top rake is to some extent lost in the tool soon becoming dull.

In the tables the first column shows the number of the experiment, the second the average compression as taken from the diagram, the third the pressure in pounds on the axis of the spring as calculated from the average compression, the fourth the force at the center of the cut, i. e., the product of the pressure on the axis of the spring into the length of the driver arm divided by the distance from the center of the piece operated upon to the center of the cut, (the last given in column eight). The depth sheared given in column six depends upon the obliquity of the cutting edge of the tool, and the depth of cut, column seven, shows the depth sheared per pound of force at the center of the cut. Columns nine, ten, and twelve give respectively the side rake, the top rake, and the clearance as already explained. The eleventh column shows the angle obliquity of the cutting edge, α. See Fig. 3.

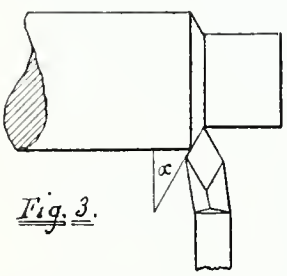


Fig. 3.

The tools compared were all of the class known as the diamond point or front tool. The angles of top rake range from zero to twenty degrees. The side rake from twenty-five degrees to ten degrees. The table shows that between the first and last tools compared there was a difference of over one and one third times the smaller value, or 134.4 per cent. With tools having twenty-five degrees side rake, the average increase in cutting value for each five degrees of top rake was 18.73 per cent. With twenty degrees side rake the increase was 23.8 per cent. and with ten degrees the increase was 38.63 per cent. For all the exper-

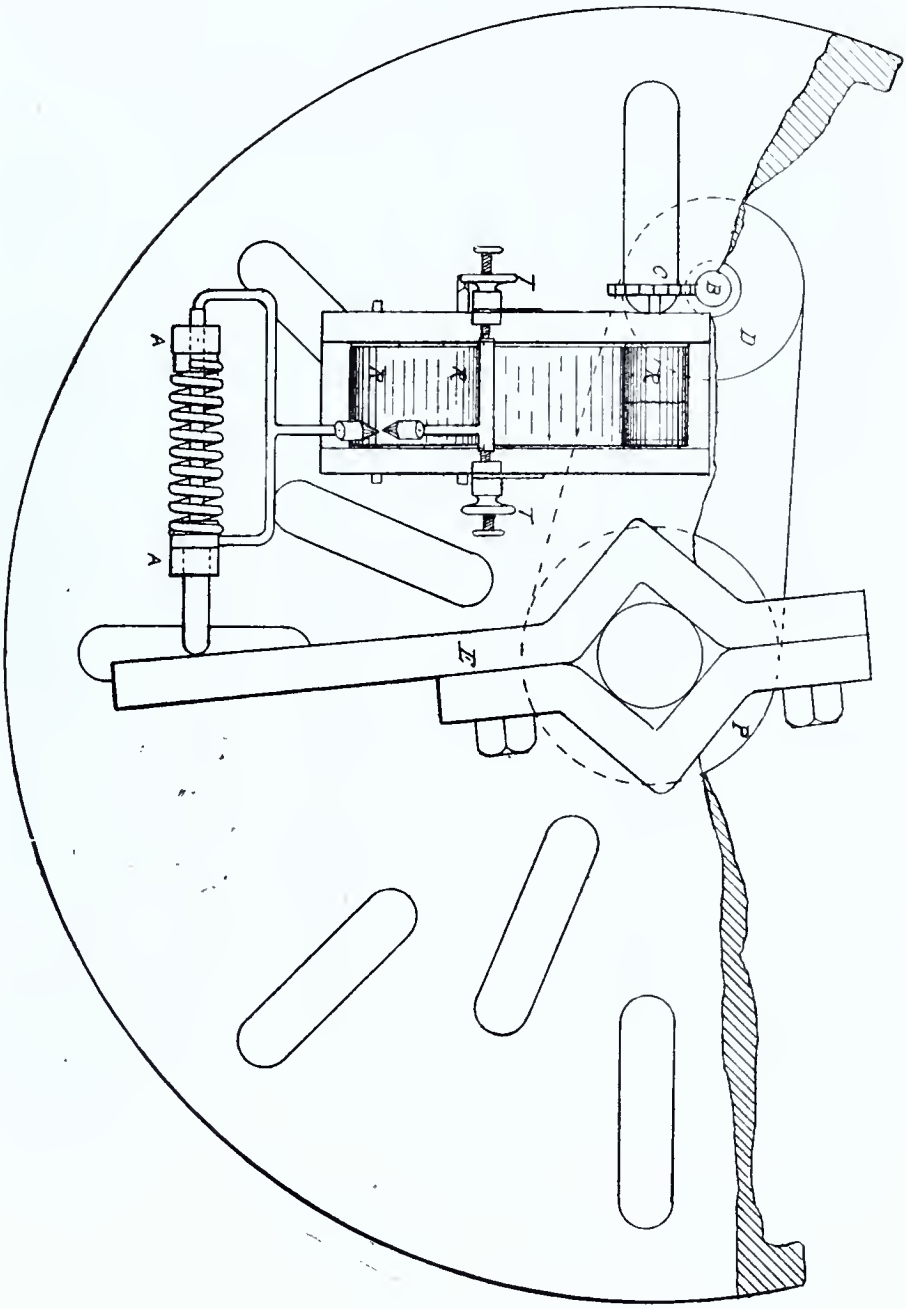


Fig. 1.

iments without regard to side rake, the average increase in cutting value for each five degrees of top rake was 21.6 per cent.

TABLE I.—DATA OF TESTS OF LATHE TOOLS.

1	2	3	4	5	6	7	8	9	10	11	12
No of Card	Average Compression in inches.	Pressure on Spring in pounds.	Force at Center of Cut in pounds.	Depth of Cut in inches.	Depth Sheared in inches.	Depth Sheared per pound.	Short Arm in inches.	Side Rake.	Top Rake.	Obliquity of Cutting edge	Clearance.
1	.382	72.58	426.97	.125	.144	.000341	1.02	25°	0°	30°	30°
2	.350	66.50	391 17	.125	.146	.000373	1.02	25°	5°	32°	30°
3	.265	50.10	294.70	126	.145	.000493	.89	25°	15°	30°	30°
4	.320	60.50	409.88	.125	.144	.000371	1.02	25°	10°	30°	30°
5	.190	36.10	274.17	.107	.126	.000459	.79	25°	15°	33°	30°
6	.200	38.00	288.60	.108	.125	.000379	.79	25°	10°	30°	30°
7	.255	48.45	326 63	.125	.144	000382	.89	25°	10°	31°	30°
8	.218	41.42	248.51	.109	.127	.000511	.72	25°	15°	32°	30°
9	.158	30.02	342.00	.109	.129	.000376	.68	20°	0°	33°	26°
10	.160	30.40	268.20	.094	.112	.000417	.68	20°	4°	33°	26°
11	.165	31.35	272.20	.101	.119	.000437	.68	20°	6°	33°	26°
12	.255	48.45	326.63	.125	.144	.000382	.67	20°	9°	33°	26°
13	.168	31.90	248.50	.101	.119	.000479	.77	20°	15°	32°	26°
14	.230	43.70	296.80	.125	.146	.000487	.87	20°	15°	32°	26°
15	.120	22.80	235.80	.109	.130	.000552	.58	20°	15°	35°	26°
16	.140	26 60	234.70	.117	.140	.000596	.68	20°	15°	34°	26°
17	.140	26.60	338.20	.094	.109	000322	.67	15°	0°	32°	22°
18	.240	45.60	305.59	.094	.109	.000356	.89	15°	0°	31°	22°
19	.212	40.28	272 90	.094	.110	.000403	.89	15°	5°	32°	22°
20	.260	49.40	296.40	.117	.137	.000462	1.00	15°	15°	32°	22°
21	.270	51.30	304.66	.109	.126	000412	1.01	15°	10°	31°	22°
22	.265	50.35	497.30	.109	.126	000253	1.01	10°	0°	30°	18°
23	.235	40.65	411.06	.094	.109	.000265	.89	10°	0°	31°	18°
24	.260	49.40	403.40	.117	.135	.000335	.74	10°	5°	30°	18°
25	.305	57.95	319.00	.109	.126	.000395	.75	10°	5°	30°	18°
26	.240	45.60	305.59	.094	.113	.000378	.78	10°	10°	34°	18°
27	.240	45.60	438.78	.148	.175	.000400	.78	10°	10°	32°	18°
28	.220	41.80	277.12	.109	.131	.000472	.905	10°	15°	32°	18°
29	.330	62.70	427.50	.164	.192	.000449	.88	10°	15°	32°	18°
30	.320	60.80	409.88	.351	.412	.001010	.98	10°	20°	32°	18°
31	.245	46.55	358.80	.148	.175	.000615	.78	10°	20°	32°	18°

MANUFACTURE OF VITRIFIED SEWER PIPE.

By Wm. C. Klingelhoefer, '92, School of Civil Engineering.

The process herein described is that used by the well known firm of Evens & Howard, St. Louis, Mo., to whom the writer is indebted for information kindly furnished. Their mine and factories are located at Howard Station, on the Missouri Pacific, and St. Louis & San Francisco railroads. The sizes manufactured by them vary from 3 to 24 inches in diameter, and the capacity of their works is 100 tons of pipe per day, which is equivalent to a mile of 10-inch pipe, a half mile of 15-inch pipe, or one fifth of a mile of 24-inch pipe.

The ingredients of the clay from which the pipe is made are as follows:

Fire clay,	-	40%.	-	SiO_2 - -	43.93	
				Al_2O_3 } -	40.09	
				Ti_2O_2 }		
				H_2O. - -	13.80	combined.
				Free Silicon,	0.60	
				K_2O. -	0.20	
				Fe_2O_3. -	0.88	
				H_2O. -	0.50	hydroscopic.
					100.00	

Surface soil,	-	40%	
Yellow clay,	-	15%	} "grog."
Burned pipe,	-	5%	}
		100	

The fire clay is mined near the works, from a vein 8 to 10 feet thick and 60 feet below the surface. It is of a grayish color, its specific gravity is 1.75, and its hardness is one half to three fourths, taking talc as one and diamond as ten. It is mined in the same manner as coal. That for pipe is molded at once, while that intended for brick, tile, and retorts is weathered by dumping in a pile and allowing rain, frost, etc., to pulverize it. The surface soil is the ordinary dark soil on the surface, and is taken as it is needed. The loamy clay is used to reduce the cost of material and to reduce the temperature required for vitrification.

The clay is prepared for molding by being passed through the "dry mill" and then through the "wet mill." The dry mill con-

sists of a horizontal rotary disk, or pan, in which roll two heavy wheels. The disk is of cast iron and is 9 feet in diameter ; that portion upon which the wheels grind is solid, while the portion from the wheels outward is perforated, so as to allow the finely ground material to drop through. The disk is fixed to a vertical shaft, which carries at its upper end a mitre wheel, which latter gears with a similar wheel on the main shaft. The wheels are of cast iron, with hard cast-iron tires which can be replaced when worn out, are 4 feet in diameter, and weigh 6,000 pounds each. They are mounted on a horizontal axle, which is free to slide between vertical guides, are placed four feet apart and rotate by contact with the horizontal disk.

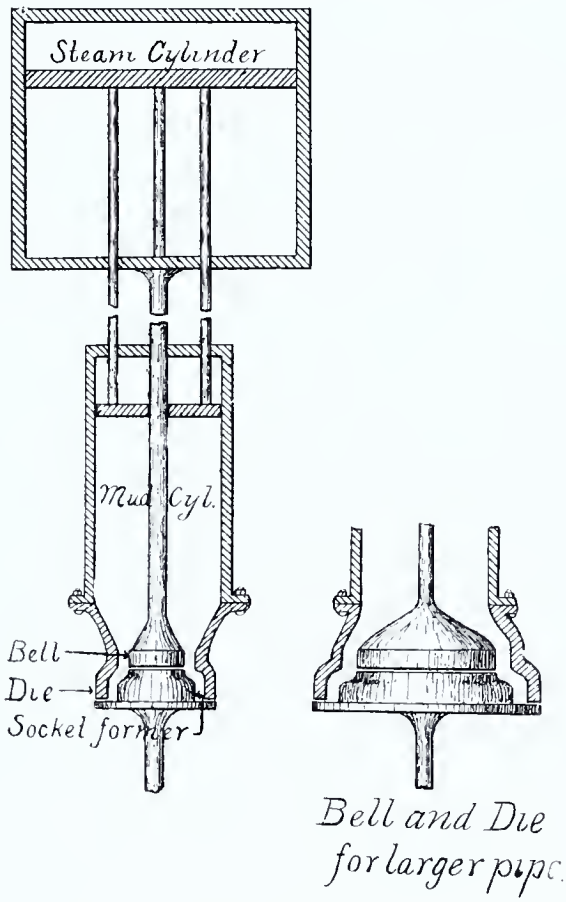
Into this dry mill the fire clay and grog are thrown and ground. The material on leaving the wheels is thrown outward by the rotation of the disk, the fine material falls through the holes in the disk and the coarser particles are again brought under the wheels by two scrapers at opposite parts of the pan. The finely ground material is carried over a set of screens ; that which passes the screens goes to the bin, while the coarser particles again return to the dry mill.

The wet mill differs from the dry mill in that in the former the disk is not perforated and the wheels weigh 3,500 pounds each instead of 6,000 pounds. Otherwise the two are alike.

From the bin the dust is allowed to run into the wet mill where it is mixed with water and re-ground until it forms a paste. Then the surface soil is added, and the whole wetted and ground until it forms a stiff mud, when it is delivered, by means of a scoop, into the elevator which conveys it to the press.

The press consists of a steam cylinder and piston, a mud cylinder and piston, the bell, the die, and the bell or socket former. The steam piston is 40 inches in diameter and is connected to the 20-inch mud piston by means of three rods. When the steam pressure is 90 pounds per square inch the pressure exerted by the mud piston is 360 pounds per square inch.

The mud cylinder is vertically underneath the steam cylinder, and has attached to its lower end the die. This die is of cast iron. Its lower end shapes the outside of the bell, or socket, of the pipe. Above the socket former the die is a right cylinder for two or three inches. This part shapes the body, or straight portion, of the pipe. Above this the die is divergent or convergent, as the pipe is smaller or larger than the mud cylinder. The bell also is of cast iron, two or three inches of its lower end being a cylinder of a diameter equal



to the inside diameter of pipe. Above this part the bell is made tapering to connect it with a heavy rod which passes through the mud piston and is fastened to the steam cylinder. The bell hangs in the center of the mud cylinder and die, with its bottom flush with the bottom of the cylindrical part of the die. Inside the die, and even with the bottom of the bell, is a knife which travels in a circle and cuts the pipe to the desired length.

The socket former is a cast-iron disk with holes perforated in its surface, and is equal in diameter to the inside diameter of pipe socket. It is fastened to the top of a vertical rod, and is held in place by means of hooks on the lower part of the die.

When the mud and steam pistons are at their upper limit, the socket former is put in place and the mud cylinder filled with mud, steam is admitted and the mud is forced by the mud piston and conical bell into the die. When the mud oozes through the holes of the

socket former the socket of the pipe is finished. Then the socket former is released and it descends, and the straight part, or body, of the pipe is formed as the mud is forced out of the mud cylinder between the die and the bell. When of proper length the pipe is cut off by the knife.

All sizes of pipe can be made in the same press by changing the bell, the die, and the socket former. Curved pipe are molded by moving the bell slightly to one side, allowing the clay to be forced out faster on one side than on the other.

Junctions are deftly made by hand. A hole is cut in the side of the larger pipe by a knife, the smaller pipe is trimmed or mitred to fit it at the proper angle, and the joint is plastered up with clay. This is done while the pipes are green, and no pattern is used or measurements taken.

The pipe is next conveyed to a room heated by steam pipes, where it is set on spigot end to dry, remaining from 3 to 15 days, according to the weather.

When the pipes are perfectly dry they are stacked up in the kiln, spigot end downward, the small ones inside the larger ones. The bottom layer of pipe is set on extra rings provided for the purpose; otherwise they would be damaged by cracking. The kiln is essentially the same as the down-draft kiln used in burning farm tile, but the heat used is considerably greater. After the kiln is filled with pipe all doors are closed and the contents gradually heated, coal being used for fuel.

The time of burning depends upon the size of the kiln, kind of clay, etc., but usually is about five days. The temperature of the kiln and the progress of the burning are determined by means of small clay test pieces placed within reach in the kiln. When the pipes have nearly reached the point of vitrification, the heat is raised to between 1,400° and 2,500° F, and a shovelful of common salt is thrown in on the fire. This is repeated three or four times in an hour. The salt is volatilized in the presence of moisture, hydrochloric acid is disengaged, and the sodium unites with the silicon of the clay, forming with the silicate of alumina a fusible double alkaline silicate or glaze on the pipe. This glaze is a union penetrating the surface and forming part of the pipe instead of being a mere skin. For perfect glazing it is necessary that the salt be used when the temperature of the kiln corresponds to the temperature both of the fusion of the pipe and of the fusible condition of the glaze. Such glazing

renders the pipe non-absorbent and impervious and gives it a smooth, slippery surface. A barrel or less of salt is used for a 20-foot kiln, 15 feet high. Sometimes a single dose of salt is used, much less than the preceding. Sweepings from packing houses are utilized. This finished, the fires are banked, and the annealing process is effected by allowing the kiln to cool down slowly, requiring from four to five days.

In drying and burning, the various sizes of pipe shrink about 10 per cent. in length and 10 per cent. in diameter, so that each pipe is molded five forty-eighths of an inch larger per inch of diameter than its desired diameter.

In burning, under-vitrification is better than over. When overburned, blisters show on the surface, the material expanding and appearing in layers and the pipe becoming rotten. If underburned, the pipe has the appearance of clay.

The following table is given as representing the usual list prices of manufacturers. Variations in price are made by changes in the discount. While these discounts fluctuate with the demand, etc., they are usually as much as 75 or 80 per cent. on pipes not over 12 inches in diameter, 70 per cent. on 18-inch, and 60 per cent. on 24-inch pipes, when bought in car lots. 12-inch pipes cost, then, about 15 cents, 18-inch 45 cents, and 24-inch $1.00.

LIST PRICE OF VITRIFIED, SALT-GLAZED SEWER PIPE.

Inside Diameter.	Straight Pipe, per foot.	Curves and Elbows, each.	T & Y Junctions, each.	P & Running Traps, each.	Double Junctions, and Breeches.	Increasers, Decreasers and Slants.	Weight, per foot.	Area, in inches.	No. of feet in Carload of 12 Tons.
Inch.							Lbs.		
3	$ 0 15	$ 0 50	$ 0 60	$ 1 70	$ 0 90	$ 0 45	7	7	3400
4	20	60	80	2 10	1 20	60	9	12	2700
5	25	75	1 00	2 50	1 50	75	12	19	2000
6	30	1 00	1 20	2 90	1 80	90	16	28	1500
7	35	1 25	1 40	3 50	2 10	1 05	20	39	1200
8	40	1 50	1 60	4 00	2 40	1 20	25	50	1000
9	50	1 75	2 00	5 00	3 00	1 50	27	64	890
10	60	2 10	2 40	6 00	3 60	1 80	33	78	730
12	75	2 75	3 00	8 50	4 50	2 25	41	113	600
15	1 00	3 75	4 00	.....	6 00	3 00	60	177	400
18	1 50	4 75	6 00	.....	9 00	4 50	85	254	280
21	2 00	6 75	8 00	.....	.....	.....	105	345	230
24	2 50	8 00	10 00	.....	.....	.....	140	455	170

ITEMS OF CONSTRUCTION FROM THE WORLD'S FAIR.

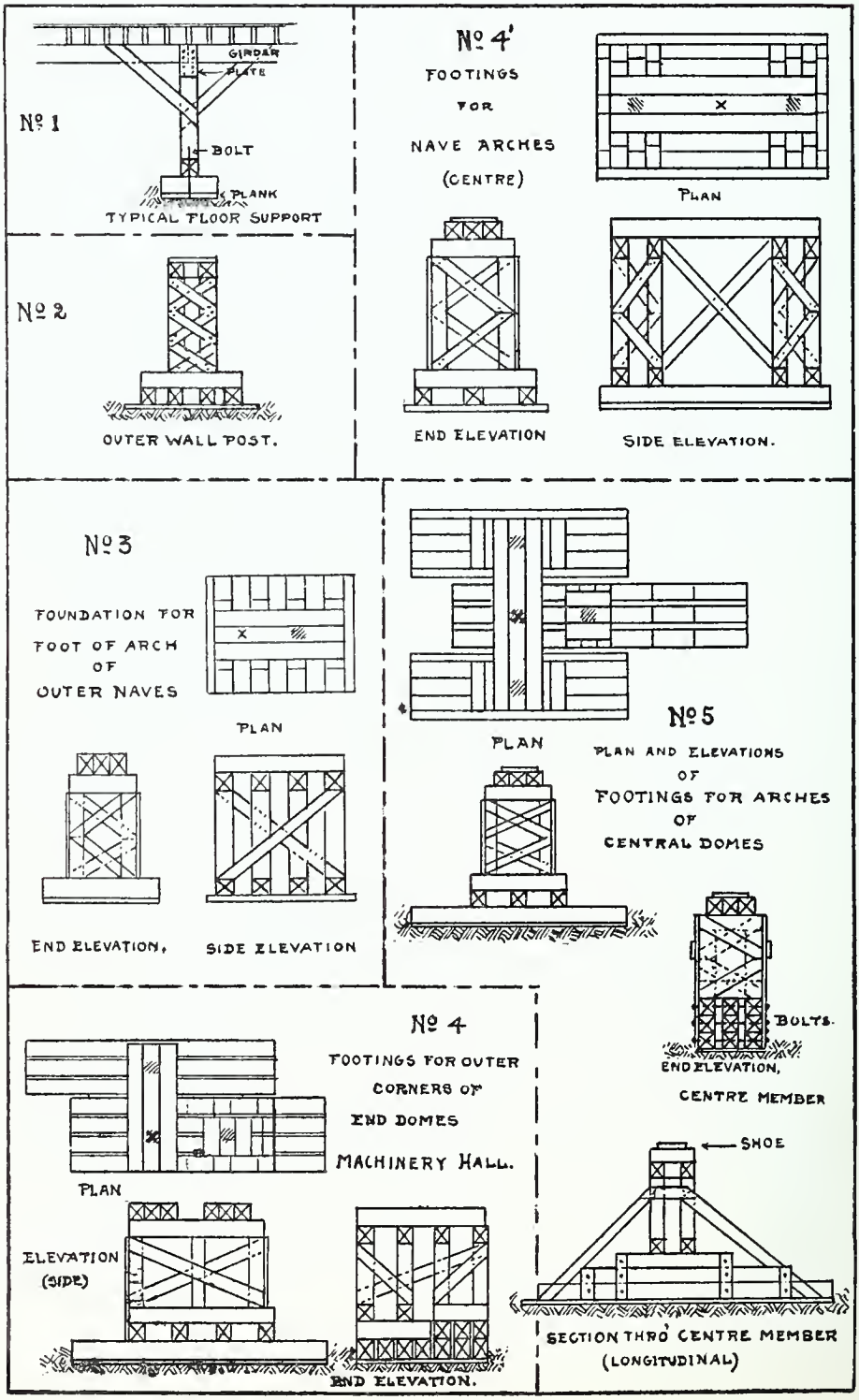
By F. W. Clark, '91, School of Architecture.

On the 12th of October, 1892, the magnificent buildings of the World's Columbian Exposition will be formally dedicated. The almost magical erection of these stately palaces, already so nearly completed in Jackson Park, Chicago, is in a great measure typical of the development of the new world in the last four centuries. Imagine nearly one-third of the land area of a park of 685 acres, covered by buildings which surpass in size and rival in architectural grandeur, excellence of disposition, and perfect adaption to the uses for which they are designed, all buildings ever constructed for similar purposes. The stupendous scope and magnitude of this enterprise is understood by few and only a thorough study of all the departmental functions of the Exposition Company could ever give one an adequate idea of it. As I have said, however, the buildings serve as an index of the extent and intent of the whole enterprise. When we consider that just one year ago, where now stand the triumphs of the skill and ability of our American architects, there was then a dismal swamp, and that the preliminary dredging that was found necessary, had scarcely been begun, we see that the Construction Department of the World's Columbian Exposition has accomplished wonders. Since that time 1,000,000 cubic yards of earth have been removed, foundations for a dozen of the more important buildings have been laid, and the superstructures of most of them so far advanced as to be clearly expressive of their final appearance.

Summary of the Eleven Main Buildings.

NAME.	DIMENSIONS.	AREA.	COST.
Administration	260 x 260 feet.	1.6 Acres.	$ 450,000 00
Agricultural, B	500 x 800 "	9.2 "	450,000 00
Horticultural, B	250 x 1,000 "	5.3 "	300,000 00
Fisheries, B	163 x 363 "	2.2 "	200,000 00
Mines and Mining	350 x 700 "	5.6 "	260,000 00
Machinery Hall	500 x 1,350 "	17.1 "	1,200,000 00
Transportation	250 x 960 "	5.5 "	280,000 00
Fine Arts	320 x 500 "	4.8 "	600,000 00
Electricity	345 x 700 "	5.5 "	375,000 00
Manufactures	786 x 1,687 "	30.5 "	1,000,000 00
Women's	200 x 400 "	1.9 "	250,000 00
Total,		89.7 Acres.	$ 5,365,000 00

The problem the Construction Department had to solve, was to erect these great buildings with a minimum amount of time, labor and material, and yet obtain a maximum efficiency in strength and rigidity. To accomplish this, as all of the buildings but one are of a temporary nature, somewhat different methods have been used than are ordinarily employed on buildings of a more permanent character and of less magnitude. In stating these methods I shall omit all dimensions, for these are dependent upon conditions peculiar to each building and impossible to generalize. The foundations in use are of three kinds, designed to meet the special requirements of the superstructures imposed upon them and the nature of the soil upon which they rest. As will be remembered the major part of Jackson Park was swampy and therefore there is a large area of made ground on which buildings are erected. It is easily understood that in such parts the necessity for pile foundations occurred. One-half of the Agricultural Building is on piles, and they also are used where exceptionally heavy loads occur, as under the dome of the Administration Building and the heavy trusses of Machinery Hall. The ordinary methods for pile foundations prevail, and the sills and girders on which the superstructure rests are secured to the piles wherever necessary, with bolts and plates. Brick foundations occur in but one case, the Art Building, in which brick walls are used with continuous concrete footings. The other, and by far the most universal foundation employed, is that of wooden piers and timber footings. These footings are sunk at least four feet into the ground, the depth and form varying according to the exigencies of the case, and they consist in the main of a post or a combination of posts extending into the ground and securely fastened by a wooden or special iron shoe to a short timber, generally of the same section, and a length determined by calculation. The latter rests horizontally upon other timbers slightly longer, which in turn are similarly placed as regards others below them. The final tier, generally the third or fourth, rests upon 3-inch planking carefully leveled upon the earth beneath. The Architectural treatment of the majority of the buildings places pavilions at each of the four corners and a dominating entrance at the center, which makes it necessary to have stronger supports at corners and centers. In fact for each building there are probably fifteen or twenty styles of footings. Sketches taken from the Machinery Hall drawings will illustrate the style and


No 1
GIRDER
PLATE
BOLT
PLANK
TYPICAL FLOOR SUPPORT
No 2
OUTER WALL POST.
No 4
FOOTINGS
FOR
NAVE ARCHES
(CENTRE)
PLAN
END ELEVATION
SIDE ELEVATION.
No 3
FOUNDATION FOR
FOOT OF ARCH
OF
OUTER NAVES
PLAN
END ELEVATION,
SIDE ELEVATION
PLAN
No 5
PLAN AND ELEVATIONS
OF
FOOTINGS FOR ARCHES
OF
CENTRAL DOMES
BOLTS.
END ELEVATION,
CENTRE MEMBER
No 4
FOOTINGS FOR OUTER
CORNERS OF
END DOMES
MACHINERY HALL.
PLAN
ELEVATION
(SIDE)
END ELEVATION.
SHOE
SECTION THRO' CENTRE MEMBER
(LONGITUDINAL)

practical development of footings for different cases far better than description. No. 1 represents a typical foundation for floor support only. No. 2 gives an exterior wall truss post foundation. No. 3, a foundation for the outer foot of one of the great arches of the nave. No. 4, a further development where the two arches meet. No. 5, a still further modification to accommodate the three arches which meet in forming the central dome of the building. On all of these sketches points marked X will be noticed which provide footings for subordinate posts supporting the small arches running longitudinally, and of the same form as those that span from No. 2 to No. 3.

In the construction of the wall is to be found the peculiar and distinctive feature of the method adopted. In covering such large areas, an immense amount of material would be used, if some means of economy were not devised. The walls consist of trussed posts, intermediate studding, and the external and internal covering, but the extensive and almost universal application of diagonal sheathing and bracing constitutes the essential difference between this temporary construction and the more permanent one which would ordinarily be used.

The trussed columns and piers are of all shapes and consist of posts at the salient and re-entrant angles, tied and bridged securely on the interior, both horizontally and diagonally, and sheathed on the outside with diagonal sheathing of ⅞-inch stuff, laid in alternating directions on each side of the pier. Sometimes solid sheathing is used, but oftener spaces are left between the boards. This forms a very stiff column, but one of great lightness. The walls are built of double sets of single studding, the dimensions of which as also the distance between centers are determined by special calculations. Where a double line of studding occurs the outer is securely tied to the inner and rests upon the same wall plate system. At required intervals over the sheathing are nailed furring strips, blocks and lookouts, with a variety of braces and devices where projections are great and the possibilities for supports are limited. The former serve as grounds for lath and staff covering, while the latter provide a basis or form for the various embellishments which denote the architecture of the building and give it its aesthetic value, such as cornices, mouldings, panels, etc. Staff, the covering for all external surfaces and for open colonnades and loggias, is a material formed of a mixture of plaster paris, burlap and cement. On large, unbroken surfaces, it is applied to the lath while wet, and is in reality a kind

of weather proof plaster. On smaller surfaces, mouldings, cornices, bas reliefs, figured panels, etc., the staff is previously formed in gelatine moulds, and when dry is attached to the forms before mentioned, by nails or wire fastenings. The staff can be finished as marble and this will be done in several of the buildings. For columns, cylindrical staff shells are fastened in sections upon the wood framing. Interior surfaces are lathed and plastered, except in obscure or invisible places, where sheathing is substituted. Three kinds of lathing are used; expanded metal, ordinary lath, and Byrkitt's sheathing in which dove-tail grooves run the length of the $\frac{7}{8}$-inch boards. The Art Building is sheathed with the latter kind, the plaster keying securely in the dove-tail.

In dome construction, radiating trusses are used and if the dome is large there is an interior and exterior dome. The exterior one is considerably stilted and has windows in the drum, while the interior one has a circular opening left at the top, to admit the light. All large domes are covered with prepared canvass stretched over $\frac{7}{8}$-inch sheathing. Smaller domes and cupolas are roofed with staff or galvanized iron. Towers are used on only two buildings, machinery hall and the electrical palace. In such construction a series of continuous timbers are run the whole height of the tower and tied together at intervals with heavy timbers, thus dividing the entire area into comparatively small rectangles. Each of these is bridged and made rigid by diagonal struts resting upon wooden shoes notched into the vertical posts. The whole is then sheathed diagonally inside and out, and when necessary the construction is further unified by iron rods, plates, etc. Spaces over openings are treated as latticed girders.

There are many other special points which must be seen to be appreciated, and which mere description necessarily brief and without illustrations, would only make more obscure.

HORSE POWER TEST OF AN ELECTRIC MOTOR.

By H. M. Lyman, '87, School of Mechanical Engineering.

The following table gives the results of a test made on a 15-HP. motor built to operate at 220 volts potential and installed at Canton, Ohio. The Prony brake method was used, and had to be applied while the motor was being used for manufacturing purposes, necessitating the placing of the brake on a counter-shaft driven by the armature pulley. The brake consisted of a lever about eight feet long placed over the pulley, with a piece of belting bearing hard wood blocks, running from one end around the pulley and up to a screw used for tightening. Fig. 1 shows the brake in position. The lever was held in equilibrium by a spring balance attached to the floor. A small stream of water was kept constantly running on to the lever and blocks to prevent heating and sticking to the iron wheel.

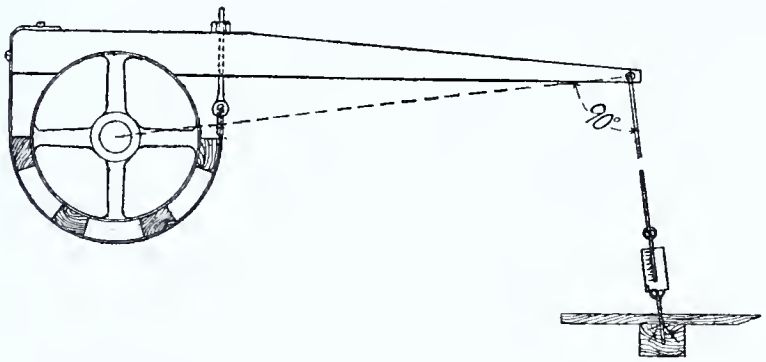


Fig. 1.

The dimensions were as follows: Length of arm to center of wheel, 7.017 feet; diameter of wheel, 1.51 feet; radius of wheel, 0.756 feet; circumference of wheel, 4.75 feet; ratio of brake arm to radius of wheel, 9.328.

The values and significations of the letters in the formulas below are given in the table on page 95.

Electrical HP., $c=\frac{ab}{746}$; $e=9.328d$; $h=4.75g$; mechanical HP., $i=\frac{he}{33000}$; efficiency, $l=\frac{k}{c}$.

Since the power consumed in the shafting, belting, etc., had to be accounted for to get an efficiency test, we had to compute it, as no

dynamometer was at hand by which it could be measured, so we took reading No. 1 (see table page 95), which gives 2.976 as the electrical HP. consumed in shafting. The mechanical HP. could not be measured, but was arrived at by aid of readings Nos. 2 and 2a. Reading No. 2 giving 8.686 electrical HP. for shafting and 4.229 HP. for the brake; hence the difference between 8.686 and 2.976 gives 5.710 electrical HP. required to give 4.229 brake HP. From these two results we find the efficiency to be 74.07 per cent. Substituting this value for the efficiency in test No. 1 we get 2.204 as the mechanical HP. consumed in the shafting, belts, etc., as no machines were running at any time while readings were being taken. This result was determined several times, and is, I believe, reasonably accurate, but is liable to slight error since a motor running at 10 amperes has not the same efficiency as when running at 30 amperes. It is assumed, however, to be constant throughout the test, and is substituted for the power consumed in the shafting in all the experiments, though it is probably a little low for those of a larger HP., as the shaft, etc., would consume more in friction when the brake was on heavily than when on lightly. In taking a reading the brake was applied and the brushes set at the same time, and when the neutral point was settled the volts and amperes were read.

The table on page 95 gives the data and results of the several tests.

The test shows that this motor is not a very good one inasmuch as only three fourths of the power taken was accounted for in useful work, while in a good motor ninety per cent. should be accounted for. The motor brushes required a swing of about one inch on the commutator for a change of current between 10 and 60 amperes, and even then sparked badly all the time. Beside it are running Edison $8\frac{1}{2}$ K. W. motors with changes of load from 2 to 8 HP. without any shifting of the brushes and without a perceptible spark.

The motor is of the common over-type pattern with bearings coming up from the yoke. The yoke and cores of the magnets are of cast iron. It was made by an amateur "electrical engineer" who claimed great things, both electrically and mechanically.

RESULT OF A TEST OF A 15 H. P. MOTOR.

No. of Test.	Amperes.	Volts.	Electrical H. P.	Pounds on Brake.	Pounds on Circumference.	Rev. of Wheel per Minute.	Travel of Circumference of Wheel.	H. P. Consumed in Brake.	H. P. Consumed in Shafting.	Total Mechanical H. P.	Efficiency of Motor. Per Cent.
	a	b	c	d	e	g	h	i	j	k	l
1	10.	222.	2.976	00.	00.	182.	.....	00	2.204	.....	.....
2	30.	216.	8.686	18.	167.9	175.	831.2	4.229	2.204	6.433	74.07
2a	19.72	216.	5.710	18.	167.9	175.	831.2	4.229	.....	.....	74.07
3	50.	220.	14.74	40.	373.1	160.	760.	8.593	2.204	10.797	73.25
4	50.	196.	13.14	36.5	340.5	160.	760.	7.841	2.204	10.045	76.44
5	50.	222.	14.88	40.	373.1	159.	755.2	8.540	2.204	10.744	72.2
6	60.	220.	17.69	49.	The Brake-Wheel Slipped on the Shaft.						
7	60.	218.	17.53	50.	466.4	166.	788.5	11.14	2.204	13.344	76.08
8	60.	218.	17.53	50.	466.4	166.	788.5	11.14	2.204	13.344	76.08

CLASSIFICATION OF ARCHITECTURAL ILLUSTRATIONS.

BY JAMES M. WHITE, '90, ASSISTANT IN ARCHITECTURE.

The following method of classifying photographs and sketches was arranged by Prof. N. Clifford Ricker to make the large collection belonging to the University of Illinois available to students of history and design. The subdivisions have been added as material accummulated and the scarcity of illustrations of some of the styles explains why subdivisions are lacking in those instances.

The architectural journals have furnished most of the material, but many illustrated books and portfolios have also been used, the most important of which are the following: Prang's History of Art, Revoil's Romanesque Architecture, Planat's Hotels Prives, Essenwein's Atlas der Architectur, Lubke's Denkmaler der Kunst and Geschichte der Architectur, Dolmetsch's Ornamentenschatz, Brandon's Analysis of Gothic Architecture, Parker's Glossary of Architecture, The Art Worker, Robinson's Architectural Foliage, Monographs of American Architecture (5 vols.), Hefner-Alteneck's Medeval Iron Work, Allen's Great Cathedrals of the World, Thomas's Japanese Sketches, and O'Kane's Modern Surface Ornament. A few hundred photographs have also been purchased from foreign and American dealers.

All the plates are mounted on standard size card boards, plates

too large for these being folded and pasted on one side only. This makes it necessary to procure duplicate copies of publications which print illustrations on both sides of a sheet. The card adopted in this case is 8-ply mounting board, 11x14 inches, and the paste is ordinary flour paste with the addition of alum and a little essence of cloves to prevent souring. For mounting photographs the addition of liquid glue will be found to facilitate matters.

The plates are arranged in portfolios, which are set on end in a case pigeon-holed to receive them. All illustrations are classified as historical or modern American. To each of the historical styles is assigned a capital letter and to each sub-style a lower case letter. Subdivisions of the sub-styles are indicated by figures. Each card is then stamped with the letters and figure of the style, sub-style and class to which it belongs If the number of illustrations of any one style is not enough to make subdividing necessary the letter of the style is stamped upon each card and that of the sub-style may be added at any future time when additions to the collection make it necessary.

By referring to the following outline it will be seen that V stands for Gothic, Va for French Gothic, and Va3 for French Gothic residences. All plates of French Gothic residences are therefore stamped Va3 and placed in a portfolio which is stamped Va3 on the back, or which has on the edge of the shelf below it a card stamped Va3. It will facilitate expanding and revising the collection if these cards are simply slipped into tin clips instead of being tacked or pasted to the shelf.

When there are not sufficient cards in one style to fill a portfolio there is no objection to grouping several together if each card is properly stamped and the same stamp also appears on the edge of the shelf below the portfolio.

The classification of the modern American illustrations differs from the above only in the use of capitals for both main divisions and subdivisions, but a different color stamping ink is used to prevent any possibility of confusion. This system has proved to be admirably adapted for the purpose, but would not be applicable in all its divisions to any collection other than the one for which it is now used, though the general scheme and the main divisions will serve as an excellent basis for subdivisions which will suit any collection. An index sheet containing the system of classification should always be near at hand to facilitate reference.

The University of Illinois collection now numbers about 8,000 cards and about 2,000 more will be added during the coming summer.

Classification of Historical Illustrations.

A. Egyptian.
B. Assyrian.
C. Persian.
D. Sassanian.
E. Phœnician.
F. Jewish.
G. Pelasgian, Greek.
H. Pelasgian, Asia Minor.
I. Etruscan.
J. Chinese.
K. Japanese.
L. Indian.
M. Mexican.
N. Peruvian.
O. Pueblo, etc.

P. Grecian
1. Principal Monuments of Athens.
2. Views of Athens.
3. Other Principal Monuments.
4. Lesser Monuments.
5. Doric Order.
6. Ionic Order.
7. Corinthian Order.
8. Scale Details.
9. Architectural Details.
10. Industrial Art.
11. Color Decoration.

Q. Roman
1. Principal Monuments of Rome.
2. Other Principal Monuments.
3. Lesser Monuments.
4. Orders.
5. Scale Details.
6. Roman Views.
7. Architectural Details.
8. Color Decoration.
9. Industrial Art.

R. Early Christian.

S. Byzantine
1. Color Decoration.
a. Armenian.
b. Servian.
c. Russian.

T. Mohammedan
a. Spanish.
b. Turkish.
c. North Africa.
d. Egyptian.
e. Persian.
f. Indian.

U. Romanesque

- a. Italian
  - 1. Principal Monuments.
  - 2. Lesser Monuments.
- b. French
  - 1. Principal Monuments.
  - 2. Lesser Monuments.
  - 3, 4, 5, 6, 7, 8. Stone Details.
- c. British
  - 1. English.
  - 2. Scotch.
  - 3. Irish.
- d. German
  - 1. Principal Monuments.
  - 2. Lesser Monuments.
- e. Scandinavian.
- f. Spanish.
- g. Portuguese.

V. Gothic

1. Color Decoration.
2. Relief Decoration.
- a. French
  1. Principal Cathedrals.
  2. Lesser Churches.
  3. Residences.
  4. Public Buildings.
  5. Details, etc.
- b. Netherlands.
- c. English
  1. Principal Monuments.
  2. Church Towers.
  3. Lesser Monuments.
  4. Scotch.
  5. Early English Details.
  6. Decorated Windows.
  7. Decorated Doors.
  8. Decorated Details.
  9. Metal Work.
  10. Perpendicular Details.
  11. Wood Work.
- d. German
  1. Principal Monuments.
  2. Lesser Churches.
  3. Details.
  4. Public Buildings.
  5. Residences.
- e. Italian
  1. Principal Monuments.
  2. Lesser Monuments.
- f. Spanish
  1. Principal Monuments.
  2. Lesser Monuments.
- g. Portuguese.
- h. Metal Work.

W. Renaissance

- a. Italian
  1. Color Decoration.
  2. Architectural Details.
  3. Public Buildings.
  4. Principal Churches.
  5. Lesser Churches.
  6. Principal Palaces.
  7. Lesser Palaces.
  8. Sculpture.
  9. Tombs, etc.
- b. Spanish.
- c. Portuguese.
- d. French
  1. Principal Palaces and Chateaux.
  2. Lesser Chateaux.
  3. Houses.
  4. Churches.
  5. Architectural Details.
  6. Color Decoration.
  7. Public Buildings.
- e. English.
  1. Elisabethan.
  2. Later.
  3. Scotch.
- f. German
  1. Color Decoration.
  2. Public Buildings.
  3. Palaces.
  4. Residences.
  5. Churches.
  6. Architectural Details.
- g. Netherlands.
- h. Danish.
- i. Swedish.
- j. Mexican.
- k. The Orders
  1. Miscellaneous Details.
  2. Tuscan.
  3. Doric.
  4. Composite.
  5. Ionic.
  6. Corinthian.
- m. Metal Work.
- n. Old Colonial
  1. Public Buildings.
  2. Houses.
  3. Churches.
  4. Church Details.
  5. House Details.

- **X. Modern**
  - a. Italian.
  - b. Russian.
  - c. Netherlands.
  - d. French
    1. Exposition, 1889.
    2. Business Buildings.
    3. Public Buildings.
    4. Theatres, etc.
    5. Architectural Styles, 1889.
    6. Churches.
    7. Houses, etc.
    8. Houses (Colored Plates).
  - e. English
    1. Public Buildings.
    2. Schools.
    3. Hotels, etc.
    4. Churches.
    5. Church Interiors and Details.
    6. Business Buildings.
    7. Mansions.
    8. House Interiors.
    9. Houses.
  - f. German
    1. Public Buildings, except Austrian.
    2. Austrian Public Buildings.
    3. Churches.
    4. Palaces.
    5. Residences.
    6. Business Buildings.
    7. Monuments.
  - g. South American.
  - h. Canadian.
  - i. Miscellaneous Views, etc.
  - j. Engineering Miscellany.

Classification of Modern American Illustrations.

- **A. United States and State Buildings**
  - A. General U. S. Buildings.
  - B. Local U. S. Buildings.
  - C. Other U. S. Buildings.
  - D. State Buildings.

- **B. Municipal Buildings**
  - A. City Halls.
  - B. Court Houses.
  - C. Other Buildings.
  - D. Town Halls.

- **C. Business Buildings**
  - A. Stores.
  - B. Store and Office
    1. Eastern.
    2. Western and Southern.
  - C. Office
    1. Newspaper.
    2. Western.
    3. Chicago.
    4. New York.
    5. Boston and Southern.
    6. Architects.
  - D. Bank.
  - E. Exchange.
  - F. Chambers of Commerce.
  - G. Boards of Trade.

D. Exposition Buildings
- A. World's Exposition.

E. Transportation Buildings
- A. Railroad Buildings.
- B. Steamer Buildings.

F. Storage Buildings
- A. Warehouses.
- B. Storage.

G. Manufactories.

H. Hospitals
- A. Medical.
- B. Insane.

I. Asylums
- A. Homes, etc.

J. Prisons and Jails.

K. Reformatories.

L. Buildings for Refreshment and Recreation.

M. Music and Drama
- A. Music Halls.
- B. Opera Houses.
- C. Theatres.

O. Non-Christian Churches.

P. Christian Churches
- A. Cathedrals.
- B. N. Y. Cathedral Competition.
- C. Large Stone Churches.
- D. Small Stone Churches.
- E. Brick Churches.
- F. Wooden Churches.
- G. Interiors and Details.

Q. Cemetery Buildings and Monuments
- A. Cemetery Buildings.
- B. Cemetery Chapels.
- C. Tombs.
- D. Personal Memorials.
- E. War Memorials.
- F. National Monuments.
- G. Other Monuments.
- H. Equestrian Monuments.
- I. Fountains.
- J. Pedestrian Monuments.
- K. Tombs.
- L. Sculpture.

R. Educational
- A. Public Schools.
- B. High Schools.
- C. Academies.
- D. Technical Schools.
- E. Normal Schools.
- F. Professional Schools.
- G. College Buildidgs.
- H. University Buildings.

S. Museums and Libraries
- A. Museums.
- B. Small Libraries.
- C. Large Libraries.

- **T. Residences**
  - A. Cottages
    1. Wooden.
    2. Mixed.
    3. Masonry.
  - B. Country
    1. Wooden.
    2. Mixed.
    3. Masonry.
  - C. Suburban
    1. Wooden.
    2. Mixed.
    3. Masonry.
  - D. City
    1. Small.
    2. Double.
    3. Blocks.
    4. Medium.
    5. Mansions.
  - E. House Interiors
    1. Photographs.
    2. Drawings.
  - F. Details.
  - G. Apartment Houses.

- **U. Clubs and Societies**
  - A. Club Houses.
  - B. Society Buildings.
  - C. Y. M. C. A. Buildings.

- **V. Hotels**
  - A. Modern.
  - B. Mixed.
  - C. Masonry.

- **X. Miscellaneous Buildings**
  - A. Gate Lodges.
  - B. Stables.
  - C. Richardson's Works
    1. Trinity Church.
    2. Cincinnati Chamber of Commerce.
    3. Cambridge Law School.
    4. Ames Buildings.
    5. Pittsburgh Court House.
    6. Houses.
    7. Other Buildings.

- **Y. Construction**
  - A. Moulded Brick.
  - B. Terra Cotta.
  - C. Tiles
    1. Low's Art.
    2. Encaustic.
    3. Painted.
  - D. Mantels.
  - E. Towers, etc.
  - F. Miscellaneous Details.
  - G. Metal Work.
  - H. Wrought Iron Work.
  - I. Furniture.

- **Z. Ornament**
  - A. Surface.
  - B. Relief.
  - C. Shaded Drawings.
  - D. Sketches.
  - E. Decoration.

RATES OF MAXIMUM RAINFALL.

By Arthur N. Talbot, Professor of Municipal Engineering.

The maximum rate of rainfall for any locality is an important element in the determination of the size of storm-water sewers. The total precipitation during a storm is of comparatively little value for such purposes, but the intensity or rate per second or per hour during the period of time necessary to charge the sewer for its entire length is a chief consideration. It is the object of the writer to present the available data of rainfall and to show what maximum rates of rainfall may be expected.

For the purpose of determining the probable maximum rate of precipitation for any given number of minutes, the records of rainfall are extremely meager. The ordinary records of storms as reported by the Weather Bureau and by private observers generally give only the total precipitation for the whole storm, with possibly the duration of the storm. Since many of the larger storms extend over several hours, and since the intensity of the storm is very unevenly distributed, the total precipitation will bear no relation to the maximum rate. A storm giving 6 inches of rain in 10 hours may give 3 inches in 1 hour and possibly 2 inches in 20 minutes, or at the rate of 6 inches per hour. There are numerous records of daily, monthly and yearly rainfall extending back nearly a century. However valuable these may be for many purposes, they are useless in the application to the design of sewers. Long continued drizzling rains may make up a large annual rainfall in some climates, while short, heavy rains are common in some localities having a small annual rainfall. The so-called cloud-bursts occur frequently in districts having a small annual rainfall. Even where the amount falling in a short period of time is given, the result is frequently untrustworthy, since the time may not have been accurately judged.

What is needed, then, is an accurate record of the time and amount of rainfall throughout the storm. Such a record is obtained by the self-registering rain gauges, in which the amount of rainfall is automatically recorded on a sheet moved by clock work in such a way that the time of rainfall is also accurately shown. Such gauges have been in use for several years in a few cities, and in 1888 the United States Weather Bureau placed them in the principal cities of the country. It may be expected that these records will in time give valuable data for determining probable rates of rainfall.

The data herewith presented have been selected from the records given in the *Weather Review* of the United States Weather Bureau and from other records furnished the writer by the Weather Bureau, and also from the records of cities and private observers. It is divided into two parts:

1. General records of heavy storms from all stations reporting in the states considered.

2. Records of individual cities.

The reports of these storms are shown on the diagrams. The ordinates represent the rate of rainfall in inches per hour, and the abscissas the duration of this rate of rainfall in hours and minutes; thus if 2 inches fell in 30 minutes, the rate of 4 inches per hour would be platted on the 30-minute line. Notice that the *rate* of rainfall per hour is given and not the total precipitation. If the latter is wanted, the rate may be multiplied by the time.

By a study of these diagrams, two curves were deduced, one expressing the rate of rainfall which is rarely exceeded in either of these sections of the United States, and the other expressing the rate of frequent occurrence. The equation of rare rainfall is $y=\frac{6.0}{x+.5}$, where y is the rate of rainfall in inches per hour for the time x expressed in hours. This is indicated in the diagram by the upper curve. The equation of ordinary maximum is $y=\frac{1.75}{x+.25}$, where y is the rate of rainfall in inches per hour for the time x expressed in hours, or $y=\frac{105}{x+15}$, where x is the time in minutes. It is shown by the lower curve on the diagrams. These two curves give the following rates of rainfall, respectively: 10 minutes, 9.0 inches and 4.2 inches; 20 minutes, 7.2 inches and 3.0 inches; 30 minutes, 6.0 inches and 2.33 inches; 45 minutes, 4.8 inches and 1.75 inches; 60 minutes, 4.0 inches and 1.4 inches.

1. *General Records.* These are grouped together as New England and North Atlantic States, South Atlantic States, Gulf States, and North Central States, and contain all the available data of heavy storms in these states, the smaller reports being omitted from the diagrams. In the diagram for the North Central States, records from only the following states are shown: Ohio, Indiana, Illinois, Missouri, Kansas, and Iowa. As few of these records are from self-recording gauges, the duration of the storm is somewhat indefinite. There is a tendency to make the time an even 30 minutes, 60 min-

utes, etc. Generally, only one record is given for each storm. As comparatively few short periods are given, and as the heavy hour rains probably would show high 5-minute and 10-minute records, the frequency of heavy precipitation for a short period is not fairly shown by the diagram. While many of the records may be considered uncertain, yet it is probable that very many high precipitations for short periods in these same storms are unrecorded.

These diagrams represent reports from 499 stations, for periods varying from 1 year to 50 years. It is unfortunate that the indefiniteness of the reports will not permit the determination of the total number of years covered by these diagrams. Many of the records are discontinuous, reporting only occasionally and omitting many whole years. While it is liable to considerable error, the following represents the number of years' observations platted as nearly as can be judged: New England and North Atlantic, 500 years; South Atlantic, 640 years; Gulf, 1,200 years; North Central, 1,000 years. In other words these periods represent the time a station in each of the sections named would secure such a diagram.

The curve of rare rainfall is exceeded as follows: New England and North Atlantic, 6 times; South Atlantic, 6 times; Gulf, 12 times; North Central, 11 times; or, if the range of observation may be trusted, once in 83, 107, 100 and 91 years, respectively. These can not, however, be taken as proving that such rainfalls are more frequent in any one section than in another. It is the writer's belief, moreover, that such rainfalls are of more frequent occurrence than this would indicate.

The curve of ordinary maximum is reached or exceeded as follows: New England and North Atlantic, 140 times; South Atlantic, 210 times; Gulf, 315 times; North Central, 270 times; or, once in 3.6, 3.1, 3.8, and 3.7 years, respectively. While the record indicates that the curve is reached at only the point where time is reported, it is probable that the curve is at least touched at many shorter periods during the same storm.

2. *Records of Individual Cities.* Most of these records, as shown by the titles, are from self-registering rain gauges, so that not only is the time of precipitation accurately determined, but the rates for different portions of the same storm may be given. For many of the storms two to three reports for times varying from 5 minutes to 1 hour are given, so that the number of storms reported is much

less than the number of points platted on the diagrams. While the number of years the diagrams cover is small, the results are probably fairly representative of ordinary rainfalls.

The records for New York City are those furnished by the Director of the Central Park Meteorological Observatory for the years 1869–1887 and those by the Weather Bureau for 1888–1891. In the 23 years, 12 storms reached the curve of ordinary maximum rate of rainfall, $y=\frac{1.75}{x+.25}$, while 3 of these gave considerably higher results.

The records for Boston, Mass., are taken from the report of Desmond Fitz Gerald in Trans. Am. Soc. C. E., Vol. 21, for the years 1879–1888, and from the Weather Bureau records for 1889–1891. It covers a period of 13 years. 5 storms reached the curve of ordinary maximum, and no storm seriously passed it.

The records for Washington, D. C., are from the reports of the Smithsonian Institution and the Weather Bureau for the years 1871–1891. In these 21 years, storms reaching the curve of ordinary maximum rate of rainfall occurred 9 times, and only 2 storms exceeded it to any extent.

The records for Chicago, Ill., are from the reports of the Weather Bureau for the years 1889–1891. In these three years, storms reaching the curve of ordinary maximum rate of rainfall occurred twice. In addition to these, several storms occurring between 1875 and 1888 and measured by ordinary gauges are shown by crosses inclosed in circles. However, these are not reliable indications of the rainfall for short periods.

The records for Indianapolis, Ind., and Cairo, Ill., are not from self-recording rain gauges, and hence are not trustworthy. Indianapolis covers the years 1871–1891, and Cairo 1871–1888.

The records for St. Louis, Mo., are from the reports of the Weather Bureau for the years 1889–1891. In these three years, two storms nearly reached the curve of ordinary maximum rate of rainfall and none exceeded it. Additional heavy storms, occurring between 1843 and 1848, but not from self-recording gauges, are shown by the crosses inclosed in circles. A rainfall of 5.05 inches in 15 minutes, or at the rate of 20.20 per hour, has been widely quoted as occurring August 15, 1848. The *Weather Review* in different places records the time of this precipitation as 15 minutes, 1 hour, and 1 hour and 15 minutes. Since the plate was made, Prof. Mark W.

Harrington, Chief of Weather Bureau, informs the writer that 1 hour and 15 minutes is the correct time. 4.04 should then appear above 1 hour and 15 minutes.

The records for Leavenworth, Kan., are a mixture of two stations, and it is not known what dependence can be placed upon them.

In summarizing the data of the 71 years of rainfall from self-recording gauges shown on these diagrams, it may be noted that the curve of rare rainfall has not been reached in a single instance, and that the curve of ordinary maximum rate of rainfall for periods less than 40 minutes has not been exceeded to any marked degree but once. It is further probable that in each of these cities storms giving rates of rainfall for any length of storm up to 40 minutes will reach the values given by the curve, $y=\frac{1.75}{x+.25}$, at least as frequently as two or three times in ten years, though not necessarily during the same storm.

The uniformity of the maximum rate of precipitation in different parts of the United States as indicated by the data presented is quite contrary to the generally accepted opinion. Nor does there seem to be any relation between the value of these maximum rates and the total annual rainfall, as has sometimes been stated. However, even if the curve of maximum rate of precipitation is nearly the same, the frequency with which it is reached may vary considerably with the climate, and more complete data would be necessary to show what this variation is. The most prominent variation would seem to be in the total rainfall in a single storm, but rainfalls of 9 to 12 inches in 3 to 8 hours appear to be as common in Ohio and Iowa as in Mississippi and Texas.

Determination of Storm Water Reaching Sewers. Space will not permit much more than a mere reference to the relation of the maximum rate of rainfall to the quantity of storm water reaching any part of a sewerage system at the same time. Gaugings of sewers show that within the ordinary limit of sewerage districts the period of flood flow is practically of the same length as the duration of the maximum storm, and it is known that these heavy storms extend over an area larger than the ordinary sewerage district. The proportion of rainfall reaching the sewer at once depends upon the character and condition of the surface of the district drained. Portions well built up, covered with roofs and paved areas, with paved streets and well-kept gutters, give a high percentage of storm water

flow. Impervious soils, frozen ground, and steep side slopes give large amounts; while wooded and grassy areas and flat, open soils give a comparatively small amount of storm water. It is difficult to formulate what this proportion will be, but for cities it will range from nearly 1 for roofs of buildings alone down to .50 for closely built up, paved, and sewered districts. Suburban districts, paved and sewered, will give .40 of the rainfall, while districts sewered but not paved may run as low as .25.

Of the attempts to state the storm water flow in mathematical language, the Burkli-Ziegler and McMath's formulas are probably best known and most widely used. They are

$$\textit{Cubic feet per second per acre} = f\, r\, (\tfrac{S}{A})^{\frac{1}{3}} \quad - \quad - \quad \text{(Burkli-Ziegler)},$$

$$\textit{Cubic feet per second per acre} = f\, r\, (\tfrac{S}{A})^{\frac{1}{5}} \quad - \quad - \quad - \quad \text{(McMath)},$$

where S is the mean surface grade in feet in a thousand; A the drainage area in acres; r the rate of rainfall in inches per hour "during the period of greatest intensity of rain"; f a coefficient ranging from .37 for rural districts and suburbs to .90 for cities, with .62 as the mean value. Though f is called by Mr. McMath and others "the proportion of rainfall that will reach the sewer," it is a mere coefficient in the Burkli-Ziegler formula and would seem to be properly so in the other. An objection to these formulas is that while the "period of greatest intensity" may be sufficiently definite where storms have a uniform rate of precipitation throughout, in this climate a definite period of rainfall must be stated, or an arbitrary selection of r made, as in the case of St. Louis where 2.75 was decided upon. These formulas take no account of the fact that long, narrow districts will require a longer time for the storm water to reach the outlet than a compact district of the same area, and hence that the amount of storm water concentrating at the outlet will be less.

The real rate of rainfall causing the maximum discharge from a given district will be the rate which may be expected for a time equal to that necessary for the storm water from the remotest part of the drainage area to flow to and through the sewer to the point under consideration. If this time can be determined, the rate may be found from the equation of ordinary maximum rainfall and will be the rate which will charge the sewers.

The number of inches of rainfall per hour differs from the number of cubic feet per second falling on an acre by less than 1

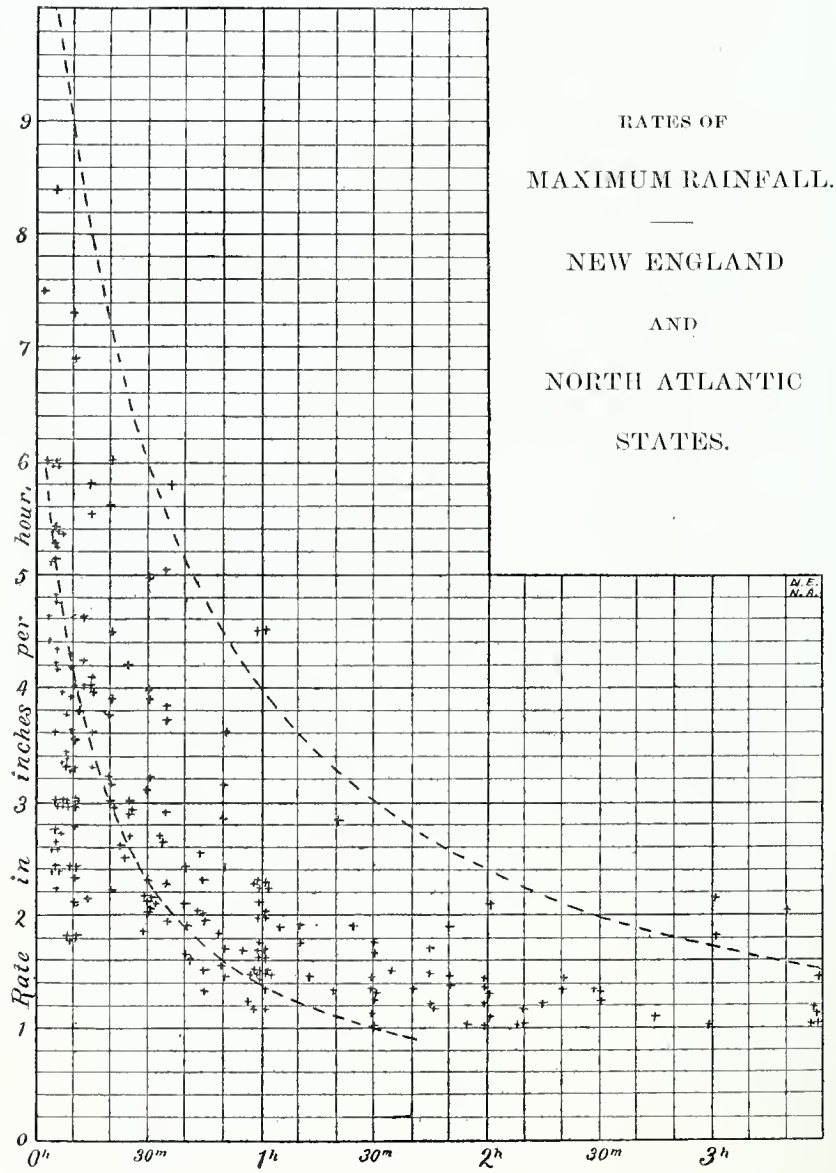
per cent., and hence one may be used in place of the other. Calling f the proportion of rainfall reaching the sewer during the maximum flow, l the length of sewer, v the average velocity in feet per second in sewer, and b the time in seconds required for the water to reach the sewer inlets, we have directly from the equation of ordinary maximum rainfall a general form of equation for the rate of rainfall reaching the sewer and hence of the storm water per acre which may be expected in such a storm,

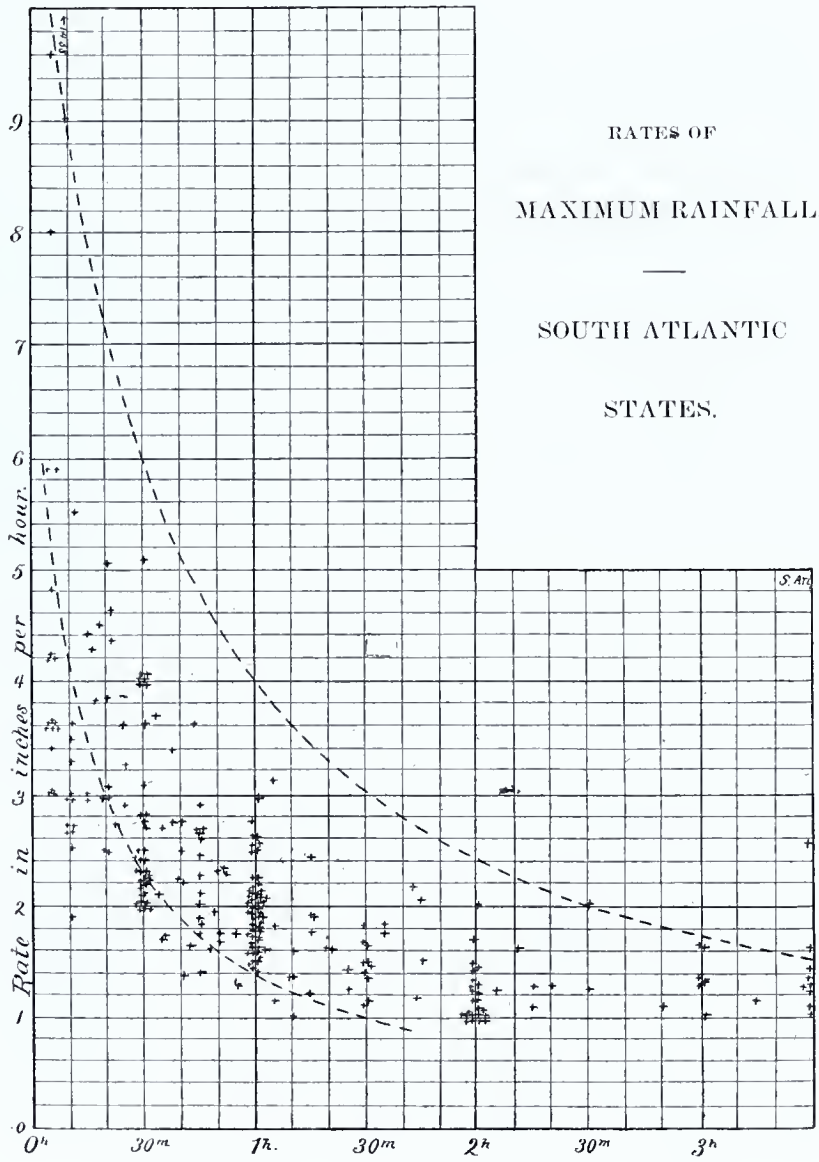
$$\textit{Storm water in cubic feet per second per acre} = \frac{f \times 6300}{\frac{l}{v} + b + 900}$$

While this method of finding the discharge has been criticised on account of the introduction of the element of time, it is at least rational and allows a much safer use of the engineer's judgment and experience, since his knowledge of its derivation will permit a more satisfactory application of his acquired data. It is hoped that more data on the proportion reaching the sewer will make this a satisfactory form.

As a matter of interest it may be added that if the proportion of length of sewer to area be 3—an average ratio—which gives $l = 360\sqrt{A}$, and if an average velocity of six feet per second be used, 300 seconds be taken as the time to reach the sewer inlet, and f be used as .50, the above formula would become for well built up districts,

$$\textit{Storm water in cubic feet per second per acre} = \frac{52.5}{\sqrt{A} + 20}$$


RATES OF
MAXIMUM RAINFALL.
NEW ENGLAND
AND
NORTH ATLANTIC
STATES.
N.E.
N.A.
Rate in inches per hour.
0
1
2
3
4
5
6
7
8
9
0h
30m
1h
30m
2h
30m
3h

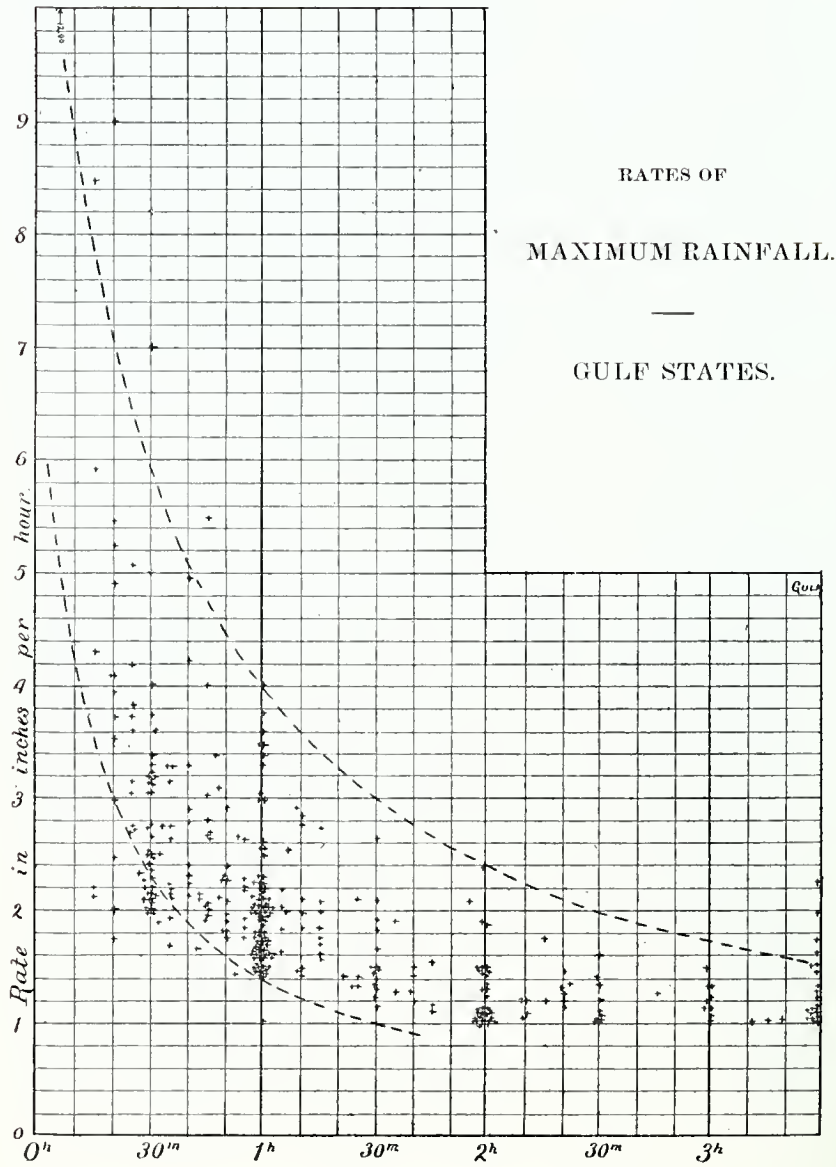


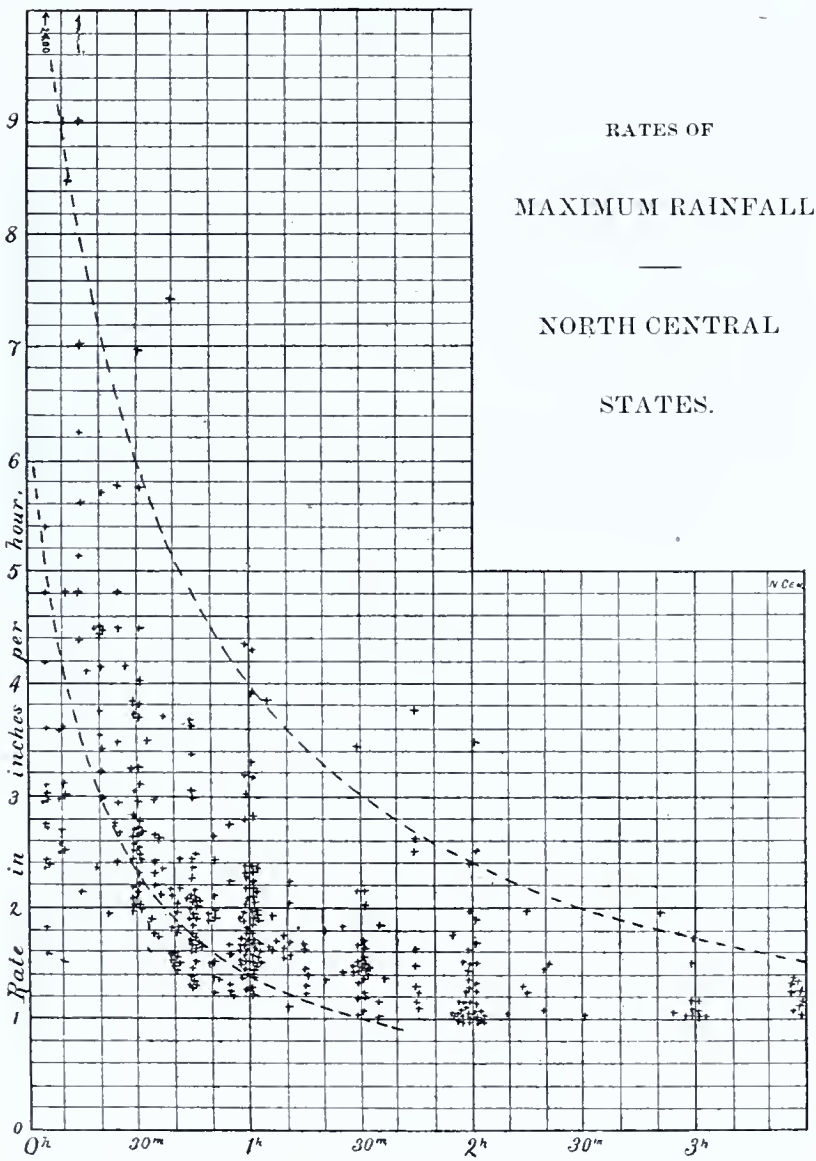
RATES OF

MAXIMUM RAINFALL.

SOUTH ATLANTIC

STATES.


RATES OF
MAXIMUM RAINFALL.
GULF STATES.
Rate in inches per hour
0
1
2
3
4
5
6
7
8
9
0h
30m
1h
30m
2h
30m
3h

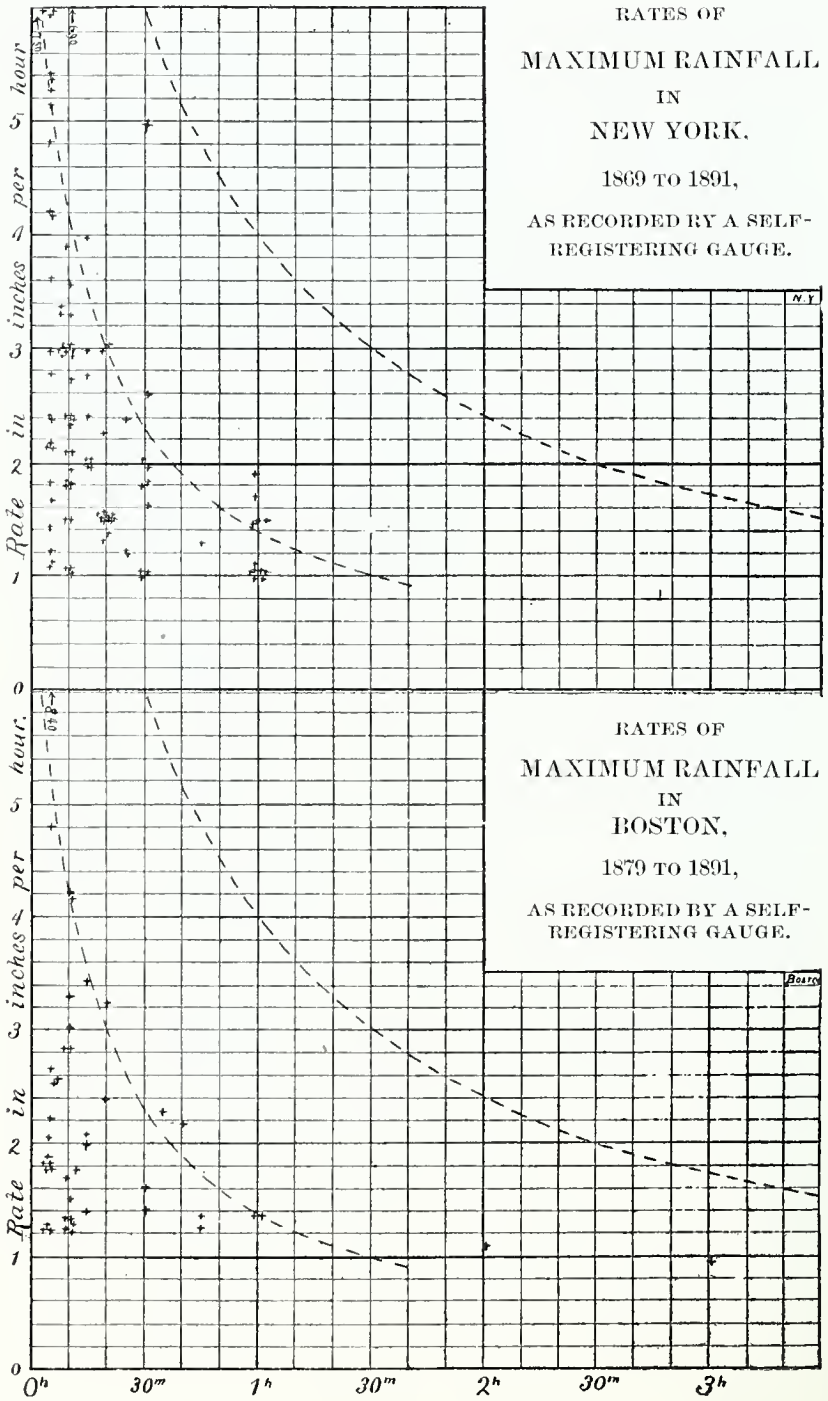


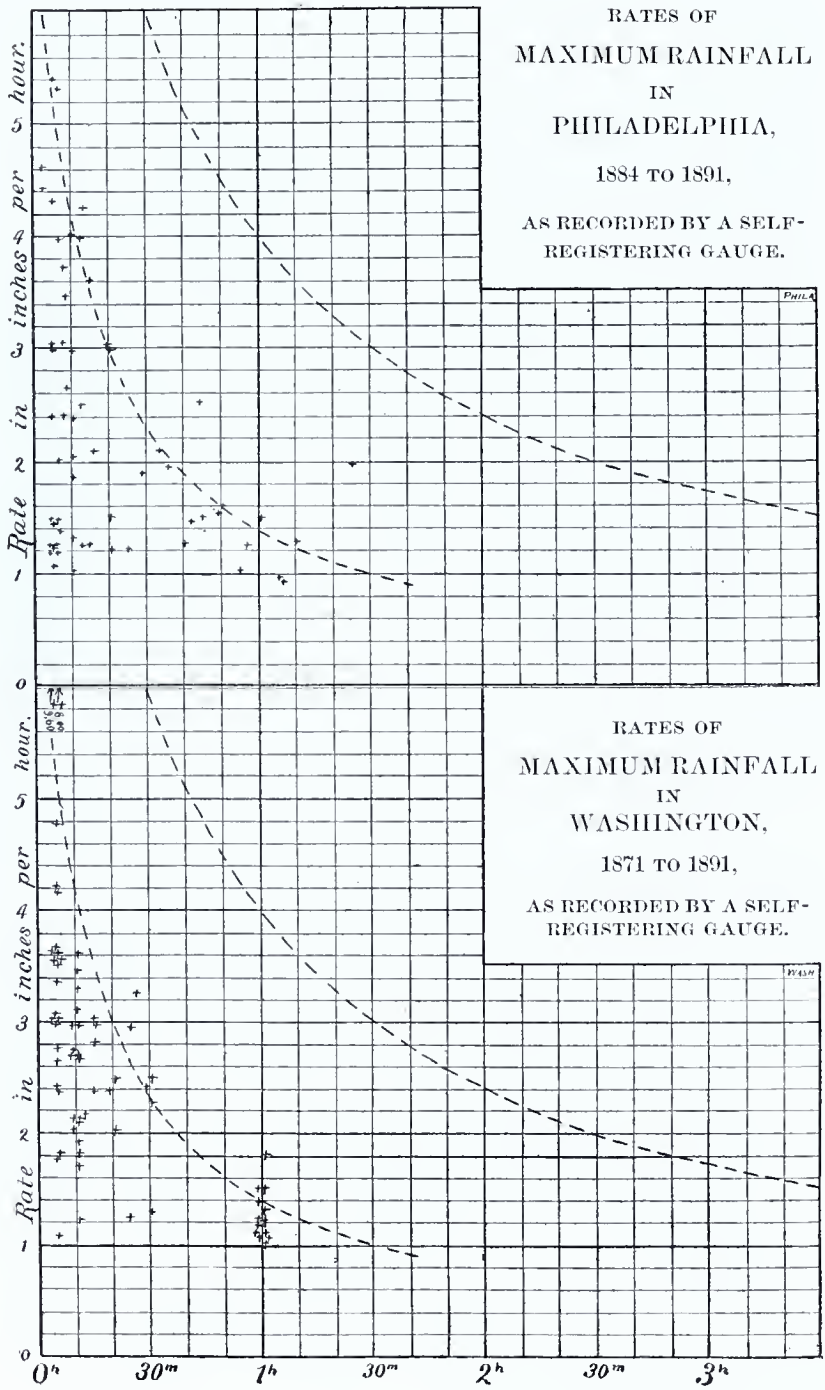
RATES OF

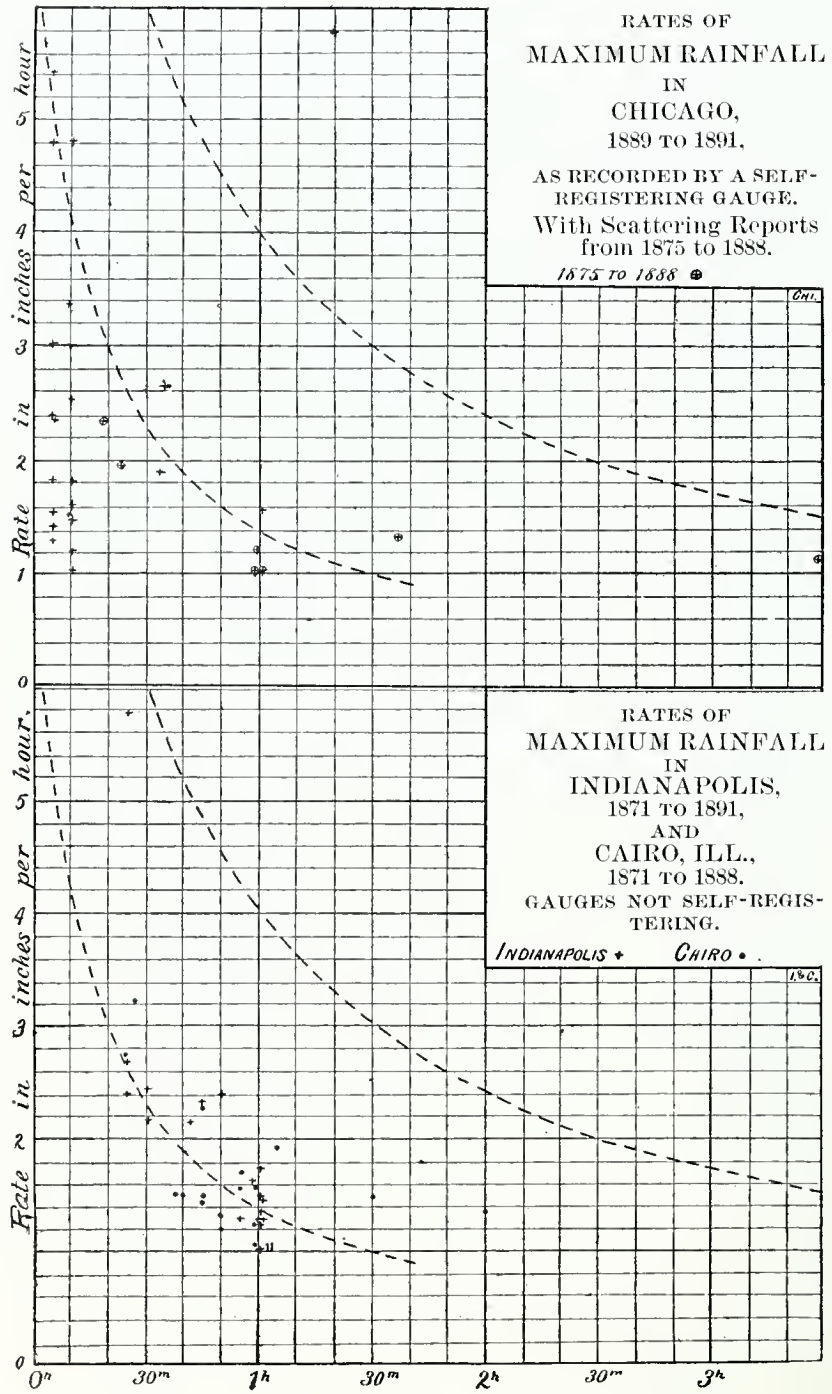
MAXIMUM RAINFALL.

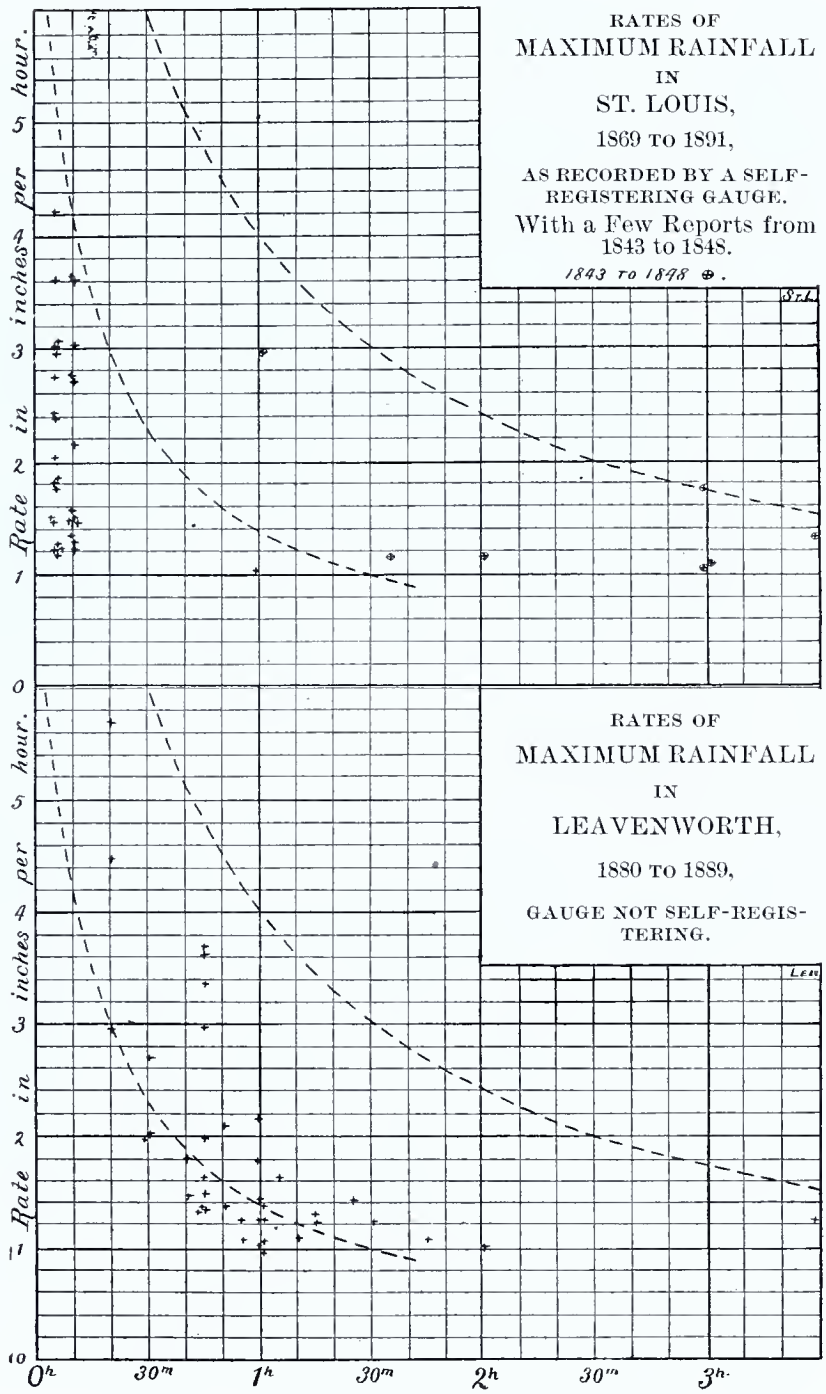
NORTH CENTRAL

STATES.


RATES OF
MAXIMUM RAINFALL
IN
NEW YORK.
1869 TO 1891,
AS RECORDED BY A SELF-REGISTERING GAUGE.
N.Y.
RATES OF
MAXIMUM RAINFALL
IN
BOSTON.
1879 TO 1891,
AS RECORDED BY A SELF-REGISTERING GAUGE.
Bosto
Rate in inches per hour.
0
1
2
3
4
5
0h
30m
1h
30m
2h
30m
3h


RATES OF
MAXIMUM RAINFALL
IN
PHILADELPHIA,
1884 TO 1891,
AS RECORDED BY A SELF-REGISTERING GAUGE.
PHILA
Rate in inches per hour.
0
1
2
3
4
5
RATES OF
MAXIMUM RAINFALL
IN
WASHINGTON,
1871 TO 1891,
AS RECORDED BY A SELF-REGISTERING GAUGE.
WASH
0h
30m
1h
30m
2h
30m
3h


RATES OF
MAXIMUM RAINFALL
IN
CHICAGO,
1889 TO 1891,
AS RECORDED BY A SELF-REGISTERING GAUGE.
With Scattering Reports from 1875 to 1888.
1875 TO 1888 ⊕
Chi.
Rate in inches per hour.
0
1
2
3
4
5
RATES OF
MAXIMUM RAINFALL
IN
INDIANAPOLIS,
1871 TO 1891,
AND
CAIRO, ILL.,
1871 TO 1888.
GAUGES NOT SELF-REGISTERING.
Indianapolis +
Cairo •
I & C.
0h
30m
1h
30m
2h
30m
3h


RATES OF
MAXIMUM RAINFALL
IN
ST. LOUIS,
1869 TO 1891,
AS RECORDED BY A SELF-REGISTERING GAUGE.
With a Few Reports from 1843 to 1848.
1843 TO 1848 ⊕.
STL.
Rate in inches per hour.
0
1
2
3
4
5
RATES OF
MAXIMUM RAINFALL
IN
LEAVENWORTH,
1880 TO 1889,
GAUGE NOT SELF-REGISTERING.
LEA
Rate in inches per hour.
0
1
2
3
4
5
10
0h
30m
1h
30m
2h
30m
3h.

COMPARATIVE TESTS OF BRICK.

By A. W. Gates, '92, and J. W. Page, '92, School of Civil Engineering.

A series of tests of brick have recently been completed at the University testing laboratory. The table below gives a summary of the results. The object of the tests was to determine the relative qualities of brick in general use for pavements, buildings, sidewalks, sewers, etc. The samples were from different makers in Illinois, Missouri, and Indiana. The values given in the table are the means for the several tests. The results given for modulus of rupture do not differ materially from those found in former tests. The values for crushing strength are higher than those usually found, which is probably due to the fact that the surfaces were accurately ground to planes on a rubbing bed, and also that the specimens were crushed between self-adjusting parallel plates.

The tests for abrasion were made by revolving the specimens for one hour in a foundry rattler, 2 feet long by 15 inches in diameter, making 25 revolutions per minute, and containing 53 pounds of foundry stars. The samples designated A. B. C. D. were intended to be used for paving brick, E, F, G, for building brick, H, I, J, for sewer brick, but the last would not fulfill ordinary sewer specifications.

Summary of Results of Tests of Brick.

Locality.	Purpose.	Number tested.	Modulous of rupture.		Crushing strength.		Water absorbed.		Specific gravity.		Loss by abrasion.		Final rank.
			Inch. pounds.	Rank.	Lbs. per sq. in.	Rank.	Per ct. of weight.	Rank.	Water-1	Rank.	Per ct. of weight.	Rank.	
A	Paving.	13	2,645	1	12,417	4	.012	2	2.2	2	5.89	3	1
B		5	1,571	4	10,114	6	0.0	1	2.22	1	3.8	1	2
C		4	2,135	2	15,232	1	3.4	4	2.06	5	6.3	4	3
D		3	1,880	3	14,268	2	1.8	3	2.11	3	7.8	6	4
E	Building.	3	1,168	6	8,379	7	10.8	7	1.9	8	10.3	7	7
F		6	1,092	7	6,228	8	14.1	9	1.74	9	13.4	9	9
G		5	890	9	6,125	9	11.7	8	1.99	6	10.8	8	8
H	Sewers	5	1,550	5	13,499	3	3.56	5	2.08	4	5.6	2	5
I		2	955	8	11,687	5	5.7	6	1.97	7	7.2	5	6
J		2	287	10	2,893	10	16.2	10	1.63	10	32.1	10	10

The numbers in the column headed Final Rank indicate the order of the sum of the ranks. The numbers in this column would indicate the relative quality of the several kinds of brick, *if* the several tests were of equal value; but they are not. It is believed that the relative value of the tests is about in the following order: (1) modulus of rupture; (2) abrasion; (3) crushing (when surfaces are ground to planes); (4) absorption; and (5) specific gravity.

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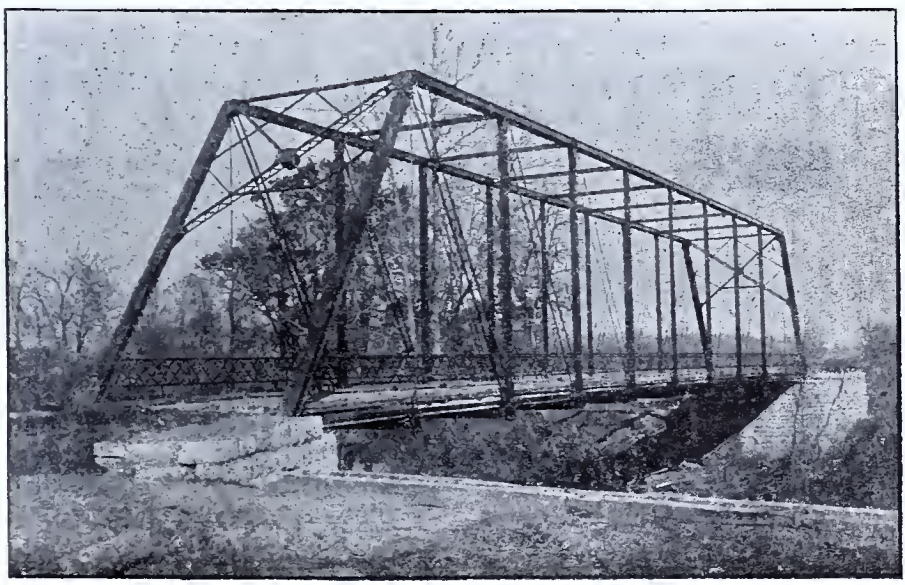

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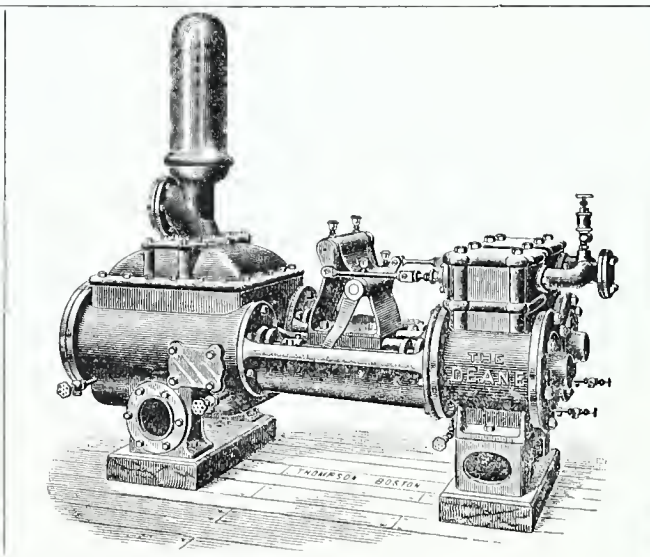

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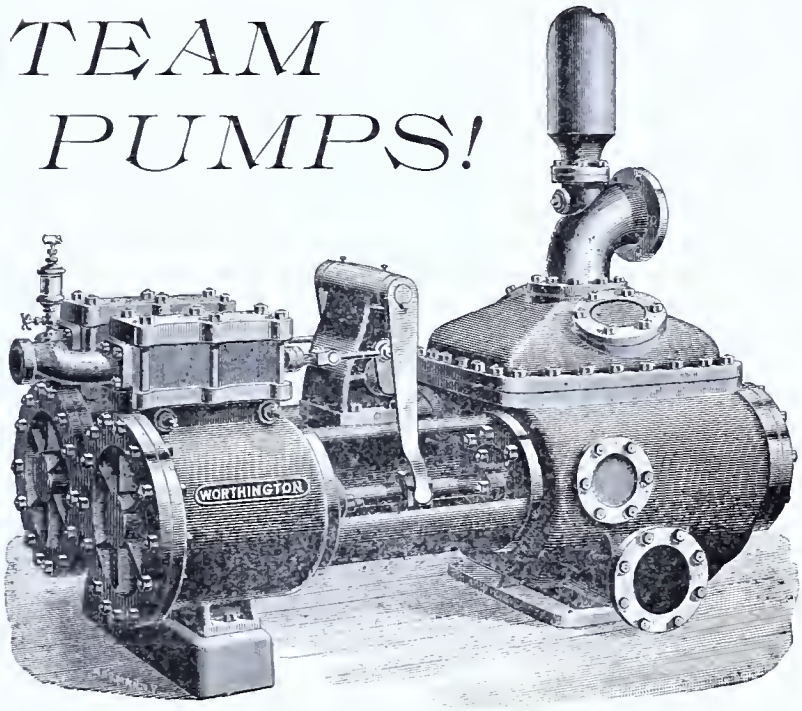

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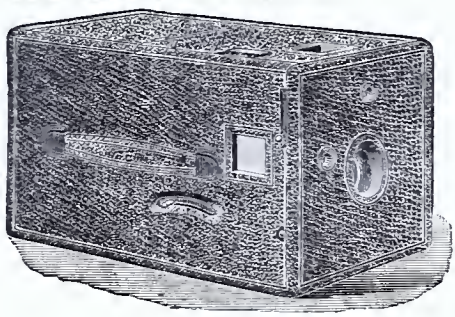

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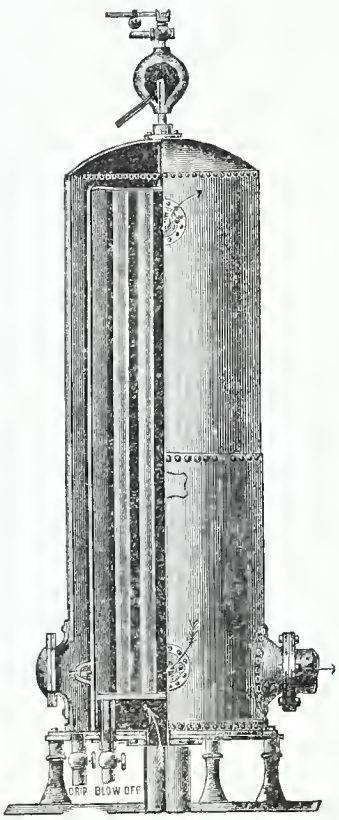

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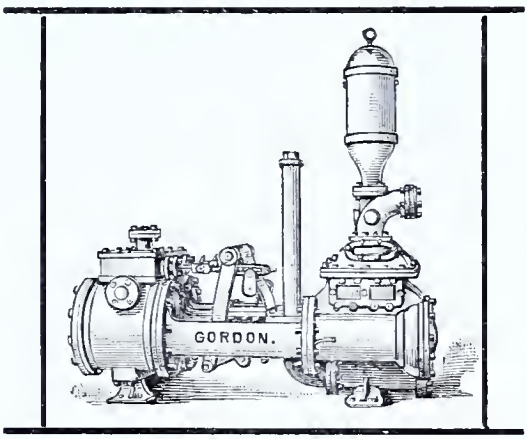

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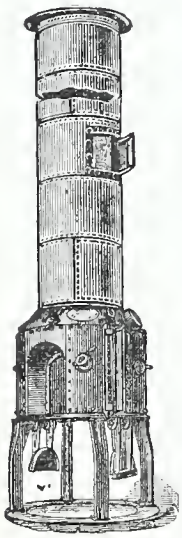

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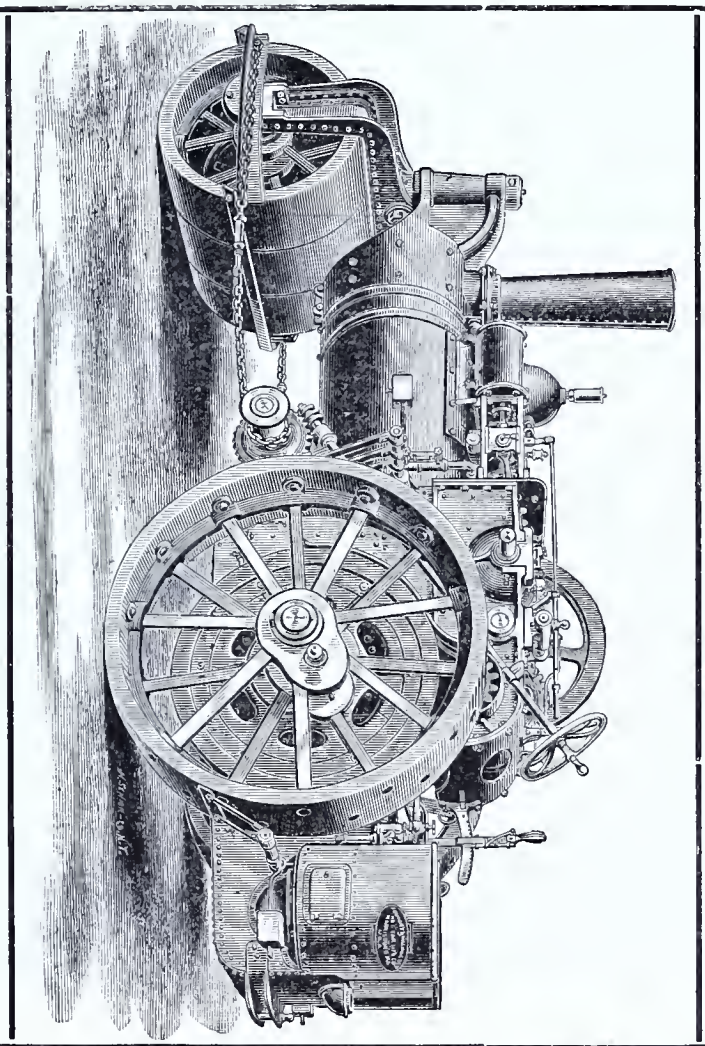

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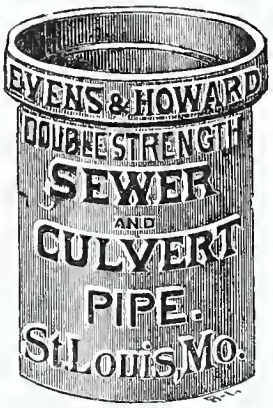

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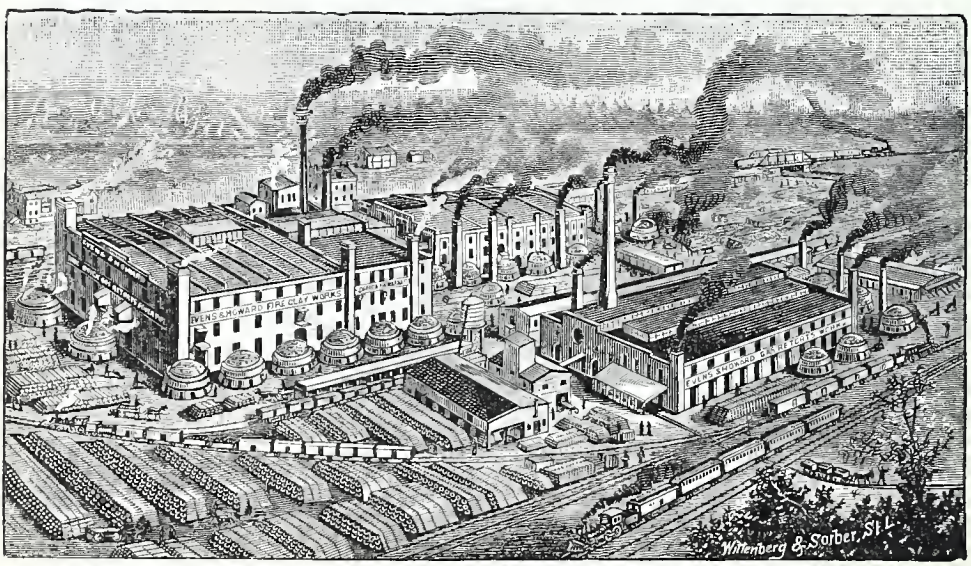

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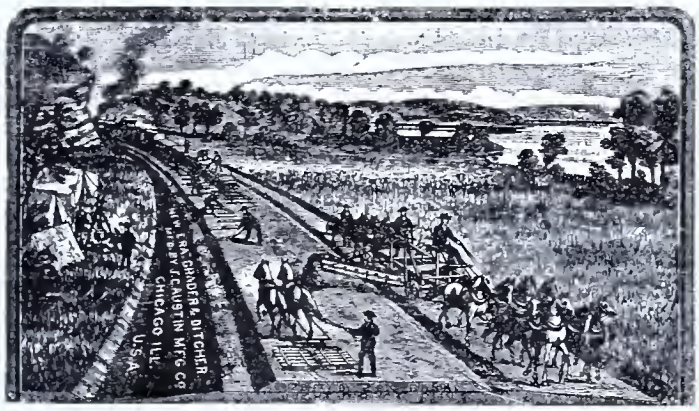

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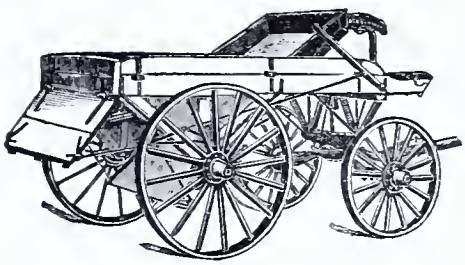

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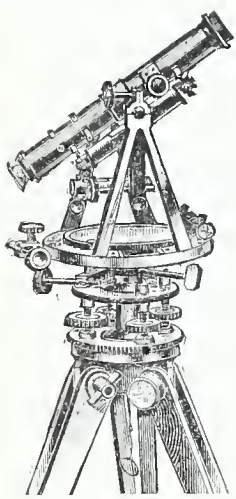
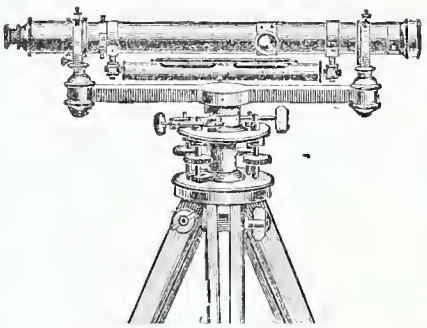
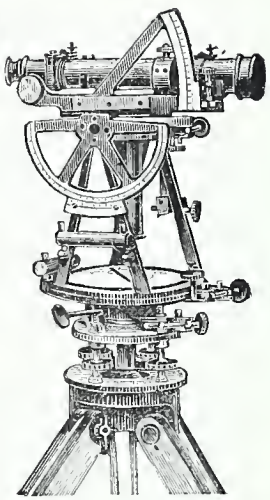

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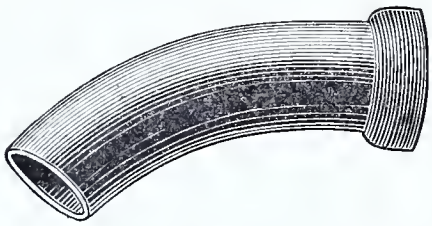

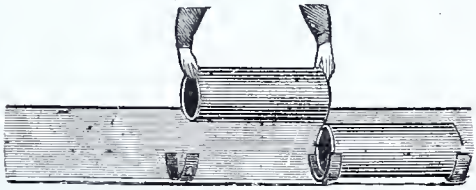

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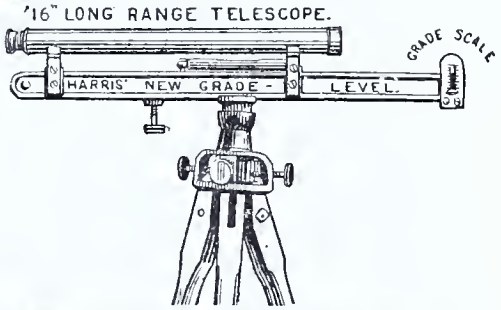

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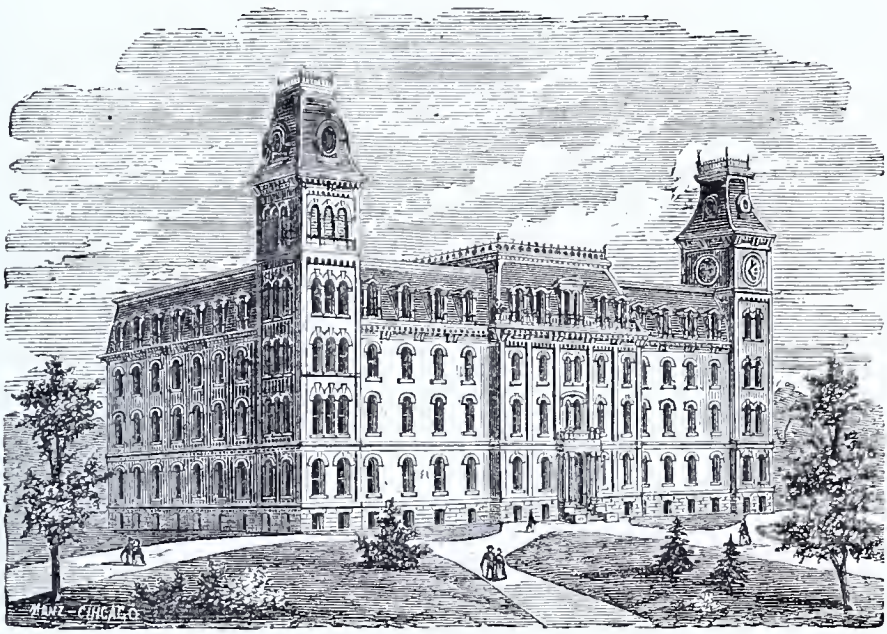

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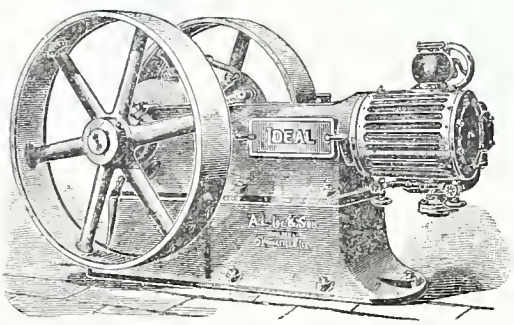

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